The Engineering Institute of Canada
2050 Mansfield Street,
Montreal, Canada

The Royal Aeronautical Society
7 Albemarle Street,
London, W.1, England

The Engineering Journal

(The Journal of The Engineering Institute of Canada)

Aeronautical Section Reprint

No. 8 August, 1937

(Issued Under Agreement Between The Engineering Institute of Canada and the Royal Aeronautical Society)

CONTENTS

CONTENTS

APPENDICES

North Atlantic Air Service[1]

London - Montreal

J. H. Parkin, M.E., M.E.I.C., F.R.S.C., F.R.Ae.S.,[2]

Director, Division of Mechanical Engineering, National Research Council, Ottawa, Ont.

Paper presented at the Semicentennial Meeting of The Engineering Institute of Canada, in Montreal, June, 1937.

Deals with factors affecting the success of a commercial air service across the north Atlantic, such as potential traffic, choice of route, weather conditions, terminal organization and facilities, aids to navigation, and type and performance of aircraft.

The outstanding feature of all recent developments in transportation is speed and in no branch, perhaps, is this feature so impressive and so important as in transport by air.

While, at the moment, air transport is restricted somewhat by meteorological and topographical factors, as are older methods of transportation to a greater or less degree, on reaching its full development in the near future, air transport will undoubtedly surmount these limitations. Full advantage can then be taken of the principal advantage of air transport, namely, speed. Air transport lines of the future will follow the great circle routes unhampered by weather or terrain.

Canada, with respect to some of the more important of the future great circle air routes, occupies a geographical position of great importance. Even before air transport reaches complete independence, and during the development of inter-continental air routes, the geographical position of the Dominion is one of no little strategic value.

It is proposed in this paper to discuss one of the intercontinental air routes, now in process of establishment, of great importance to Canada, that across the North Atlantic ocean.

Historical

The North Atlantic ocean, the great barrier to communication between Europe and North America, has been successively overcome by sailing vessels, steamships[3] (1827) submarine telegraph (1858), wireless telegraphy[4] (1901), wireless telephony (1915) and aircraft (1919). During 1936, the first regularly scheduled commercial air transport service over the North Atlantic was operated.

Since the first flights across the North Atlantic in 1919, some 85 crossings have been made by air. Of these, 65 were non-stop flights and 20 were made by stages. The non-stop flights included 31 by airship and 34 by aeroplane. Of the latter, 8 were solo flights, 26 were made from west to east and 8 from east to west. Some 68 persons have crossed the North Atlantic by aeroplane, non-stop, and 269 by stages, and about 2,682 by airship. The crossings are listed in Appendix I, and the courses of some of the more important are plotted in Fig. 1, reproduced from a previous paper.

Generally speaking, the crossings by aeroplane have been, with a few notable exceptions, purely stunt flights, undertaken with no scientific or technical objective, and have added little or nothing to our knowledge. In most of these flights, the aeroplane was more or less seriously overloaded compared with normal airworthiness standards. The exceptions include the first non-stop crossing of Alcock and Brown, on June 14th, 1919, the first solo flight of Lindbergh, the first westward crossing of Huenefeld, the east-west flight of Costes and Bellonte, the exploratory flights of von Gronau and of Colonel and Mrs. Lindbergh

[1]Without in any way wishing to detract from the impressive performances of airships over the North and South Atlantic, this paper is confined to consideration of an air service using heavier-than-air aircraft.

[2]The views and opinions expressed in this paper are entirely those of the author.

[3]It may be noted in this connection that the Royal William, a wooden vessel 176 ft. long, of 200 hp., built in Quebec in 1831, crossed to England in 1833 in twenty-five days and was the first ship to make the eastward crossing wholly under steam.

[4]The first transatlantic signal, the letter S, transmitted from Poldhu, Cornwall, was received at St. Johns, Newfoundland, by means of an aerial supported by a kite, on December 12th, 1901. Marconi was immediately invited by the Canadian Prime Minister to proceed to Canada and, as a result, a contract was entered into for the establishment of a transatlantic wireless service between Canada and Great Britain. The first messages were exchanged between the Governor-General of Canada, the Earl of Minto, and King Edward VII, in 1902, and in October 1907, the first long distance commercial service in the world was inaugurated between Glace Bay, N.S., and Clifden, Ireland.

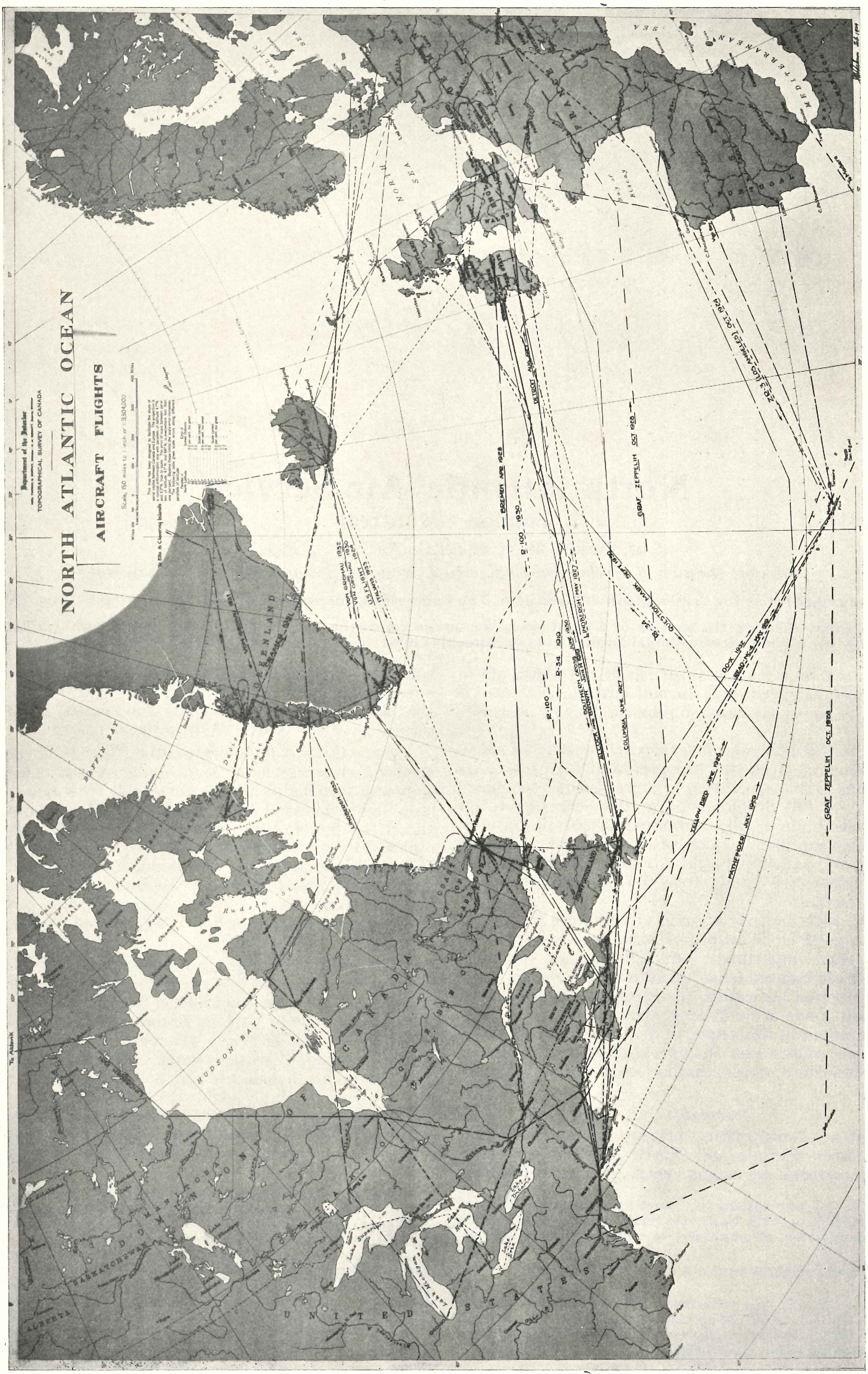


Fig. 1—Aircraft Flights, North Atlantic Ocean.

and the recent flights of the Diesel engined Dornier Do-18 flying boats.

The first and only commercial air service operated to date over the North Atlantic is that of the German airship LZ-129 (von Hindenburg) which, during the period May-October, 1936, flew ten scheduled round trips between Germany and the United States, carrying passengers, mail and express.[5]

The Barrier of the Atlantic

Regular air services now connect most of the major land bodies of the earth, with three notable exceptions. Although many flights have been made across the North Atlantic, and a smaller number across the North Pacific, regular commercial services by aeroplane are not yet in operation between North America and Europe, Asia[6] and Australia.

The possibilities in the operation of a commercial air service across the North Atlantic have long been recognized and plans for establishment of services have been made from time to time since the first crossings in 1919. Recent years have seen a quickening of interest in the project. Several nations are now actively studying proposals and, in one case, at least, preparations for a service are so far advanced that operation will likely be commenced in 1937.

Considering the inducement offered by the enormous potential traffic, it is evident that the difficulties to be overcome in the establishment of an air service between Europe and North America must be formidable.

The North Atlantic ocean has been termed "the greatest natural obstacle with which air transport is confronted." The barriers to be surmounted in overcoming this obstacle are those due to the length of the land to land flight and to the severe meteorological conditions. Up to the present time, these two have proved unsurmountable obstacles to the establishment of a transatlantic air service.

The minimum land to land distance that must be flown non-stop, if landings are not made on mid-ocean islands, is 1,850 miles, between Ireland and Newfoundland. Solely from the standpoint of non-stop flight, this range presents no particular difficulty for modern aircraft. The economic operation of a commercial service over a non-stop stage of this length and over the open sea, however, does present difficulties at this stage in the development of aircraft. The distance is considerably longer than the longest stage of any commercial air route now in operation and the overseas distance exceeds any flown commercially up to the present time.

It is generally recognized that the meteorological conditions over much of the North Atlantic ocean are, from an aeronautical standpoint, troublesome, not the least troublesome feature being the lack of knowledge pertaining to the upper air. However, as stated by Sir Napier Shaw, it would be difficult to draw a line across the ocean that could be regarded as an impossible course.

General surface climatic conditions over the North Atlantic are to-day reasonably well known. Organized weather reporting from ships at sea, observations at land stations, and the co-operation of the meteorological services of the maritime nations provide more or less adequate

[5]Average figures for this service are:—

Trip	Miles	Time	Passengers	Crew	Best time
Westward	4,351	64–35–00	48.1	56	52–48–00
Eastward	4,091	51–53–00	53.7	56	42–52–00

[6]The United States have practically completed the organization of a transpacific air service and trial flights have been made, but, at the date of writing, regular operations had not commenced.

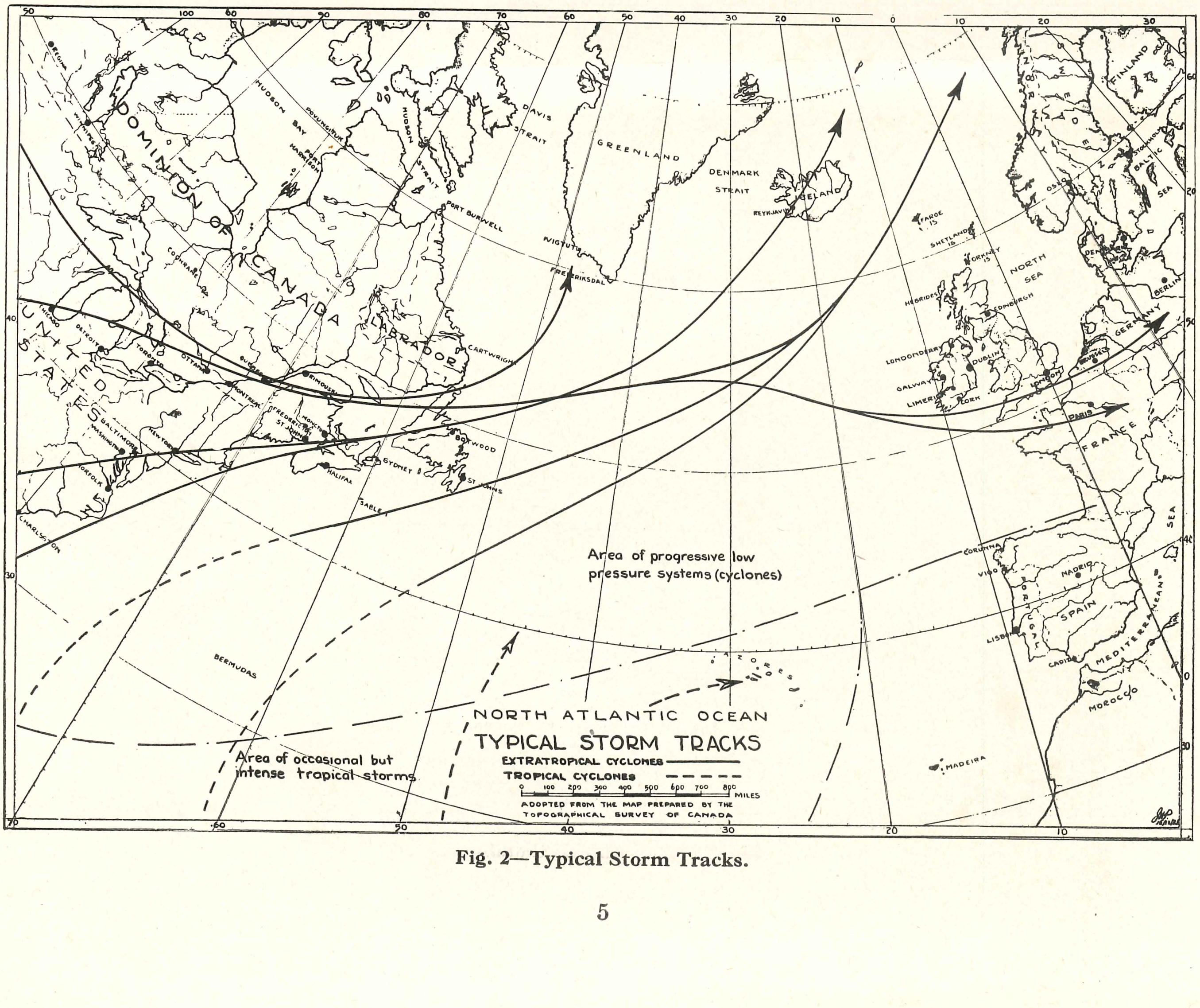


Fig. 2—Typical Storm Tracks.

information for sea-borne transport. On the other hand, knowledge of upper air conditions, so necessary to air transport, is almost completely lacking. The only information available is that collected at coast and island stations, by a few naval vessels and scientific expeditions and that obtained from the relatively few flights so far made.

The stormy character of the Atlantic ocean north of the Bermuda-Azores line is well known. The area below the line, approximately from the Bahama islands to Cape Finisterre, is subject to occasional but intense tropical storms and that above this line is characterized by frequent progressive low pressure systems or cyclones (see Fig. 2).

Perhaps the most striking fact disclosed by a study of the tracks of North Atlantic storms is that a rather well defined corridor is followed from the North American coast to Europe.

The largest number of storms enter the North Atlantic region from the Newfoundland area. Many of these have previously traversed Canada and the Northern United States. Of the storms entering by way of Newfoundland, nearly 50 per cent turn northward toward the west or east coast of Greenland. The remainder move on a course generally somewhat north of east to about midocean. Thereafter, most of these follow paths over the northern parts of the British Isles or north of them, some turn to the north and pass over Iceland and a few veer south to pass over the southern part of the British Isles.

Other cyclonic storms, frequently of great severity, develop in the Florida region or off the Carolina coast and move up the Atlantic coast and across the Atlantic along the corridor already described.

Of over 300 lows studied by Colonel Finley, 10 per cent were traced from the American to the European coast, 21 per cent were observed on one coast or the other and 32 per cent of those reaching the European coast originated over the ocean.

Tropical storms, of which the best known are the hurricanes, originate in midocean north of the doldrum area, move first generally westward and later turn north to pass over the West Indies and Gulf of Mexico. Those forming off the African coast frequently swing north in midocean and later north-eastward toward or north of the Azores. These storms, as a rule, form in September and October and average six or seven per year. They cannot be foreseen since there is little shipping in the region from which they come.

There is a definite seasonal variation in storm frequency. North of latitude 36° N. during the winter (from the middle of October to the middle of April), gales and storms are frequent. Days on which gales (wind force 8[7]

[7] BEAUFORT SCALE

Beaufort number	Description of wind: Seaman's	Description of wind: U.S. Weather Bureau	Statute miles per hour
0	Calm	Light	Less than 1
1	Light air	Light	1-3
2	Light breeze	Light	4-7
3	Gentle breeze	Gentle	8-12
4	Moderate breeze	Moderate	13-18
5	Fresh breeze	Fresh	19-24
6	Strong breeze	Strong	25-31
7	Moderate gale (high wind)	Strong	32-38
8	Fresh gale	Gale	39-46
9	Strong gale	Gale	47-54
10	Whole gale (heavy gale)	Whole gale	55-63
11	Storm	Whole gale	64-75
12	Hurricane	Hurricane	Above 75

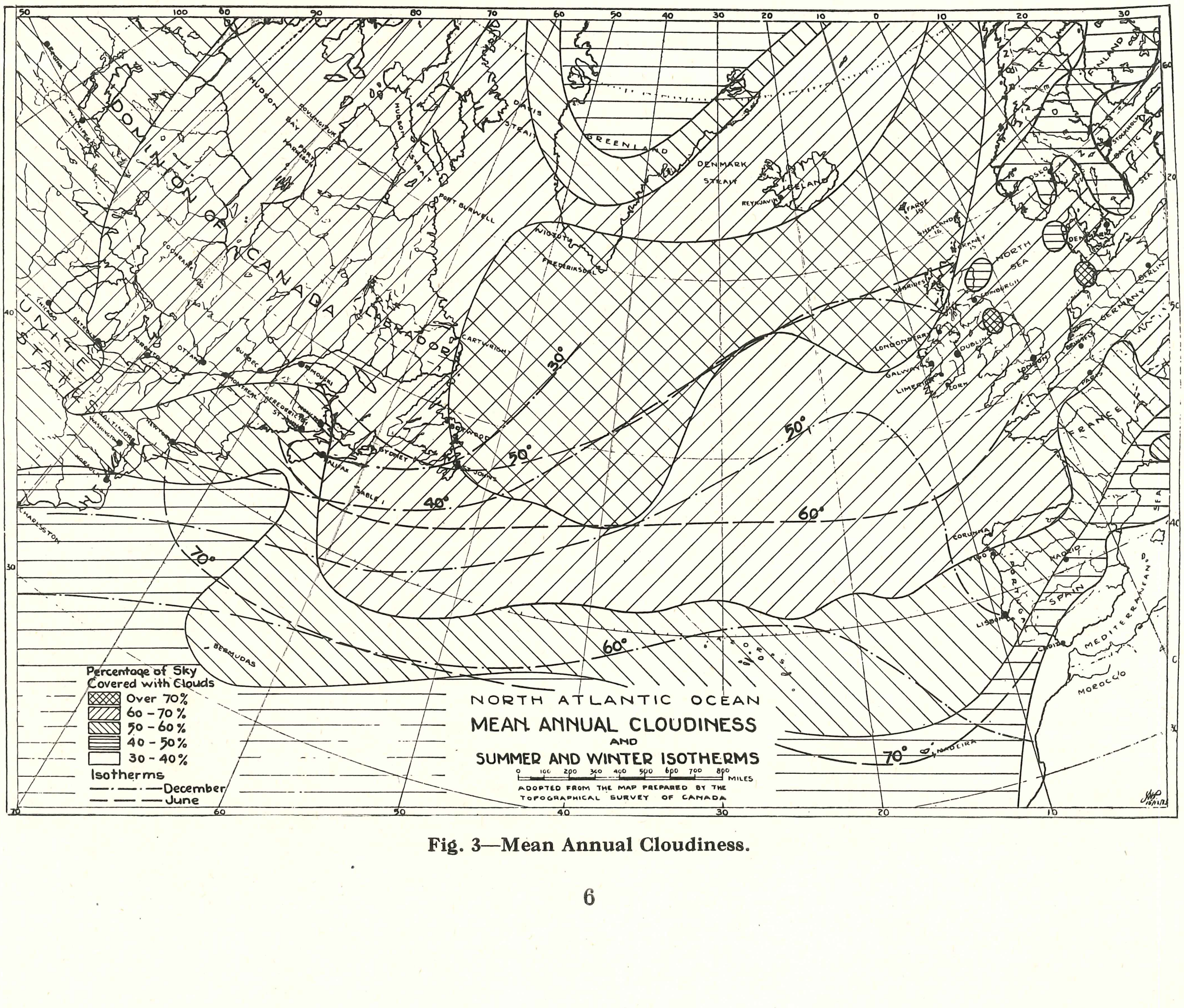


Fig. 3—Mean Annual Cloudiness.

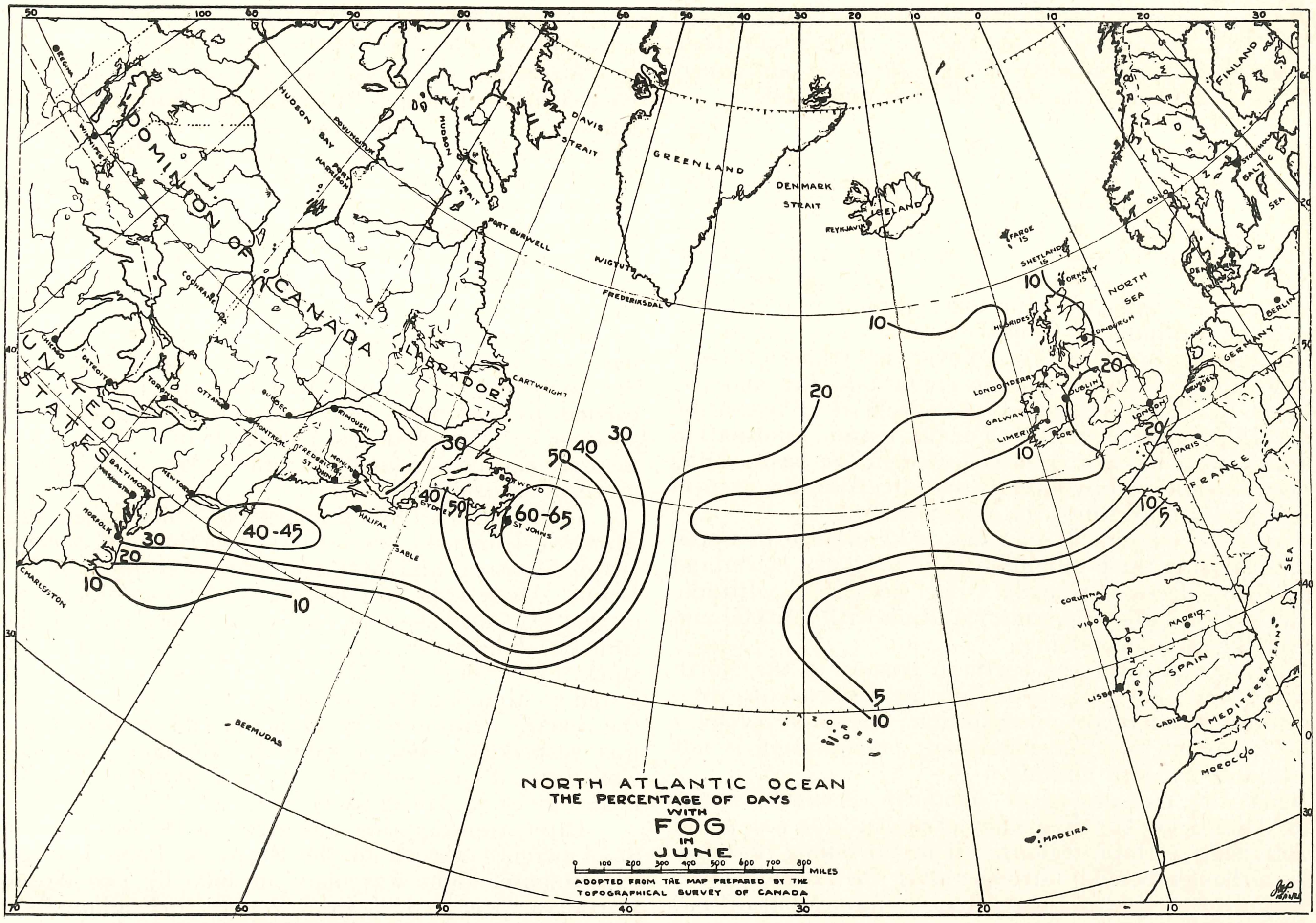


Fig. 4—Percentage of Days with Fog in June.

and below) are reported in this region may reach 20 per month; whole gales (force 10) 5 or more and winds of hurricane force (force 12) 1 or 2 and occasionally more per month. There is some indication that the frequency is greater in midocean between longitude 25° and 45° W. than near the coasts.

Information is lacking as to the height to which cyclonic storms extend. Storm areas over the Atlantic have been encountered above 10,000 ft. and in at least one case the top of the storm cloud was estimated to have extended to 20-25,000 ft.

A good deal of information pertaining to North Atlantic surface winds, their strength, direction and frequency has been collected and made available. While the average prevailing wind in the north is westerly, it varies widely in strength and direction. However, winds in the quadrant NW. to SW. predominate.

The wind direction at altitude over the ocean can only be inferred from observations made at coast and a few island stations, knowing that, for the same pressure gradient, surface winds are considerably stronger at sea than on land and blow more nearly parallel to the isobars, and that consequently the increase in speed and change in direction with height are less over the ocean than over land. Also, observed conditions at island stations are applicable to larger adjacent areas than is the case for land stations.

The average veering of the wind with altitude as observed at American coast stations indicates that, up to 2,000 ft., there is a general clockwise rotation and thereafter a veering right and left from the east until, at 12-13,000 ft., wind directions range only from NW. to WSW. Surface winds from the NW. and WNW. change little in direction with altitude. At the same time, the velocity increases with altitude. To illustrate:

A 10-mile E. wind at the surface becomes
at 5,000 ft. a 17-mile SSW. wind
at 10,000 ft. a 20-mile W. wind
at 15,000 ft. a 26-mile WNW. wind

A 10-mile W. wind at the surface becomes
at 5,000 ft. a 23-mile WNW. wind
at 10,000 ft. a 31-mile WNW. wind
at 15,000 ft. a 38-mile NW. wind

Thus easterly winds at the surface are usually shallow.

Another feature of the North Atlantic region is its extreme cloudiness. The cloudiness appears to be related to surface air temperatures. The major axis of the area of greatest cloudiness extends roughly between Newfoundland and the Faroe islands (see Fig. 3) and this line corresponds approximately with the 40 deg. surface isotherm in midwinter and the 50 deg. isotherm in summer. With surface temperatures below 50 deg. in summer, clouds may be expected.

Most clouds apparently lie below 10,000 ft. although some extend higher. The height of clouds may be estimated from the surface air temperature and humidity.

Information regarding the prevalence and seasonal distribution of different cloud types and their relation to thunderstorms, fog and mist would be of considerable value in the operation of ocean air services. Such information, while available in the mass of records of meteorological services from cloud observations made at sea, has apparently not been analysed and published in maps because of its relative unimportance to shipping.

Certain regions of the North Atlantic are characterized by dense and frequent fogs (see Fig. 4). Fogs result when steep temperature gradients of air and water are superimposed, as frequently happens off Newfoundland.

As temperature measurements indicate that the temperature in fog increases from the sea to the top, above a certain height fog is impossible and consequently fogs must be relatively shallow. This conclusion is confirmed by kite observations which show that fogs average in height from 400 to 500 ft. with occasional heights exceeding 1,000 ft. But, should an area of low pressure lie over the fog bank, the low clouds merge with the fog and poor visibility will then extend continuously from the surface to high altitudes.

Air temperatures (see Fig. 3) over the Atlantic, except as they influence other climatic conditions, fog and ice, impose no handicap on aircraft. Atmospheric ice formation is a hazard peculiar to aircraft. For this reason, information pertaining to it has not been collected in the past. Icing has been encountered by aircraft over the Atlantic, even in summer and well south of the steamer lanes.

From the standpoint of icing, a knowledge of upper air temperatures and humidity is important. Overland temperatures decrease roughly 1 deg. per 328 ft. altitude, but this rule is subject to wide variation with latitude and even for the same latitude.

Precipitation over the northern portion of the North Atlantic is high. About one-half of the observations from ships in this region report precipitation. Except as it relates to the formation of atmospheric ice, precipitation is not important to modern aircraft.

Thus the meteorological handicap peculiar to the North Atlantic is the frequency of storms, fog and cloud characterizing certain regions. The prevailing westerly winds, although possibly stronger over the Atlantic, face any east-west service and the extent of the ice hazard has yet to be determined.

The severity of the climatic conditions has not prevented the development of transatlantic shipping until the volume of traffic now exceeds that across any other sea, nor should it obstruct indefinitely the establishment of transatlantic air services.

Ship-Shore Services

In the past, lacking equipment capable of operating a transatlantic air service, efforts were made, with the available aircraft, to secure some of the advantages of air transport, by operating partial services in conjunction with steamers on the transatlantic routes.

Canada, looking forward to the time when aeronautical development would permit the establishment of transatlantic commercial air services, commenced, in 1927, experimental ship-shore air mail services. The purpose of these services was fourfold, namely:

1. The exploitation of the favourable geographical position of the Dominion with respect to Europe and steamer lanes, as a result of which, of the 3,350 miles of steamer route between Montreal and Southampton (via Belle Isle) some 1,000 miles are within the relatively sheltered waters of the St. Lawrence waterway.
2. The acquiring of experience in the regular operation of a St. Lawrence air service relative to suitable aircraft types, meteorological conditions, routes, organization and operating technique, which would be valuable when operation of a transatlantic air service commenced.
3. The speeding up of the delivery of incoming and outgoing overseas mail.
4. The demonstration of the benefits to be derived from even such a partial air service and the awakening of public opinion to the importance of Canada's position relative to the principal transatlantic air route and to the need for active Canadian participation on a major scale in the development of this route.

Aircraft of the Royal Canadian Air Force made experimental flights between Montreal and Father Point in the autumn of 1927 to advance the delivery of transatlantic mail carried by steamers using the St. Lawrence route. Ten flights were made (8 by aeroplane, 2 by seaplane) and a total of some 2,500 lb. of mail were carried with an average advance in delivery of incoming mail of thirty hours and of outgoing mail of three and a half days.

The success of these experimental flights resulted in the establishment of a regular contract air mail service between Montreal and Rimouski on May 5th, 1928, which has been operated each year since, during the season of St. Lawrence navigation (May-November). The mail is carried by aeroplane and transferred to and from the steamer by pilot tender at Father Point. Up to 800 lb. of mail are carried per flight. A brief record of this service is given in Appendix II.

In December 1929, primarily to continue the summer Montreal-Rimouski service, an experimental service between Montreal and Moncton and Saint John, N.B., was begun. Daily trips (5 days per week) were made by way of Quebec, south shore of the St. Lawrence river, Edmundston, St. John river valley to a point northeast of Woodstock, Fredericton and Moncton. Overseas mail was transferred at Moncton for carriage by rail to Halifax. In 1930, the service terminated at Moncton and on June 1st, 1931, was suspended when a general reduction was made in Canadian air mail services. A brief record of this service is also given in Appendix II.

Later, consideration was given to the extension of the St. Lawrence service to the Strait of Belle Isle and an experimental flight was made in 1930 by two aircraft of Canadian Airways Ltd. from Quebec to Bradore Bay (see Fig. 5) on the Strait just within the Canadian boundary. The 785 miles were flown between 8.30 a.m. and 5.00 p.m. and some 1,000 lb. of mail transferred to the *Empress of Australia* which had sailed from Quebec the previous day, effecting a saving in time of twenty-four hours.

In 1932, in conjunction with the Imperial Conference in Ottawa, a ship-shore air mail service was operated between Red Bay on the Strait of Belle Isle and Ottawa. Ten flights were made by aircraft of the Royal Canadian Air Force.[8] A typical schedule is given in Appendix II. Mail was delivered in Ottawa twenty-seven hours before the ship docked at Quebec, thereby saving thirty-six hours in the delivery of overseas mail. Mail posted in London was delivered as follows:

In Montreal	102 hours later
In Ottawa	104 hours later
In New York	106 hours later
In Vancouver	151 hours later

Ship-shore services by means of aircraft catapulted from the ship have also been operated from steamers plying between Europe and America. The first liner to be equipped with a catapult for this purpose was the *Ile de France* of the French line. The catapult[9] was mounted on the stern. The first flight was successfully made on August 13th, 1928, when the amphibian aircraft, with wheels removed, carrying three sacks of mail was catapulted some 400 miles at sea and landed the mail at New York sixteen hours before the ship docked. Longer flights, up to 800 miles, using a larger aircraft, were planned, but no further information on the service is available.

[8]Another demonstration of the possibilities of Canadian air mail was given in August 1933 when letters were flown from Vancouver to Quebec, placed on the *Empress of Australia*, and reached London in seven days instead of the twelve days ordinarily required for the 6,000 miles.

[9]For details of catapult and aircraft, see Appendix III.

In 1929, the Norddeutscher Lloyd liner *Bremen* was equipped with a catapult mounted on a turntable between the funnels and, in 1930, the *Europa* was similarly equipped.

The service was operated under the joint auspices of the Norddeutscher Lloyd, the Deutsche Luft Hansa and the German Post Office. The aircraft was launched at distances ranging up to about 1,500 miles, but averaging 500-700 miles from the English or American coast, depending on prevailing conditions and, eastbound, flew to Southampton and thence to Bremerhafen, and, westbound, flew via Cape Race to Sydney to land Canadian mail and thence to New York. Occasional landings were made at Boston. While proposed, the despatch of mail by seaplane to overtake the ship was, insofar as is known, not attempted.

The extra fee charged for letters, for carriage by this service, was 75 pfg. per 20 grammes. The British and United States Post Offices did not accept mail for dispatch by the service.

In spite of an early accident, when a seaplane was lost near Newfoundland, the service was operated each summer[10] from 1929 to 1935 inclusive. A brief record of the service is given in Appendix IV. The time saving ranged up to forty-eight hours eastbound and up to seventy-two hours westbound. A five-day service between London and San Francisco was rendered possible.

The service has enabled the Deutsche Luft Hansa to gather information regarding Atlantic weather, radio operation and the economic aspects of Atlantic air mail, of great value in planning a transatlantic air mail service.

[10]The catapults were removed in the fall and reinstalled in the spring.

THE TRANSATLANTIC AIR SERVICE

Object

The volume of traffic between European ports and the Atlantic ports of North America greatly exceeds that between any other two continents (see Appendix V). That much of this traffic is of a character which demands and is prepared to pay for the fastest possible service and would hence immediately make use of a reliable air service if it were available is evident from the experience of the N.D.L. ship-shore service and from the steady increase in the volume of traffic carried by long distance air services now operating.

Banks and business houses are quick to take advantage of air mail and news film companies, press photographic agencies and similar organizations use air mail whenever possible.

The transatlantic traffic demanding speed will comprise mail, express and passengers and the ultimate objective should be the operation of a reliable, fast, regular, frequent and economical service for this traffic. However, for a number of reasons, the initial service should be confined to the carriage of mail and express.

In the first place, as the figures in Table I indicate, the revenue is greater for mail and express than for passengers. Mail and express require less space and do not require the food, services, facilities, comfort and entertainment demanded by passengers. The mail aircraft is therefore smaller, more compact, less costly to build and operate, and requires a smaller crew than the passenger carrier. Operation for the first few years will necessarily be largely devoted to the acquisition of experience and information

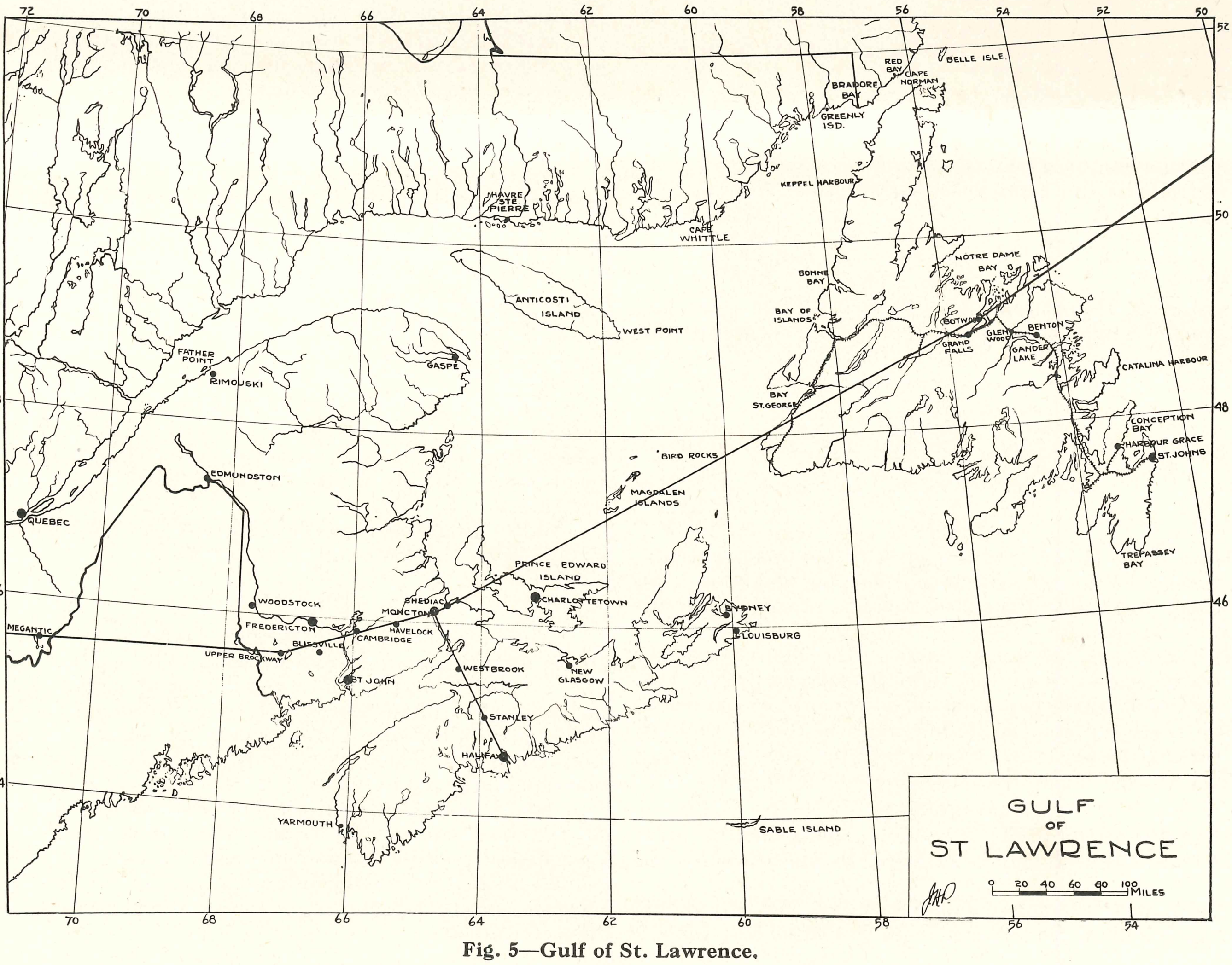


Fig. 5—Gulf of St. Lawrence.

and the crews should be free to devote themselves to this work. There is the further consideration that there will be a certain element of risk during the initial period of operation and the carriage of passengers would impose an additional strain on the crews and in addition the loss of passengers would react much more unfavourably on the project than would the loss of mail or express.

TABLE I

COMPARISON OF TRANSATLANTIC TRANSPORT RATES

	STEAMER Present average		
	Nominal	Rate per lb.	Rate per cu. ft.
Mail—letter	3c. per oz.	$1.20	$18.00*
Express	10c. per lb.	0.10	2.00
Passenger	$250.00	1.00	†

	AIRCRAFT Proposed rates‡		
	Nominal	Rate per lb.	Rate per cu. ft.
Mail—letter	15c. per ½ oz.	$6.00	$90.00
Express	$1.00 per lb.	1.00	20.00
Passenger	$500.00	1.66	4.00

Based on 40 letters per pound and a weight per cu. ft. of letters equal to 15 lb., i.e., 600 letters per cu. ft.

Based on average express package weighing 20 lb. and occupying one cu. ft. of space.

Based on average weight of passenger and baggage 225 lb.

Based on an allowance per passenger in aircraft of 75 lb. for furniture, galley equipment, food and service and a space allowance of 120 cu. ft.

*Steamers are paid about 50 cents per cu. ft.

†In steamers, excess baggage, over an allowable of 20 cu. ft., is charged for at a rate of 60c. per cu. ft.

‡Suggested by the author.

POTENTIAL TRAFFIC

The present seaborne traffic between European and North American ports is tabulated in Appendix V. In round numbers, the total yearly traffic each way is:

Mail—first class	3,600,000 lb.
prints, etc.	17,000,000 lb.
parcels	11,500,000 lb.
Passengers	300,000

Assuming 2½ per cent of the first class mail, 1 per cent of the parcel mail and none of the prints are carried by air, at the rates suggested in Table I, the volume of air mail traffic and revenue per week would be roughly as follows:

	Traffic per week Total	By air	Rate	Revenue
First class	70,000 lb.	1,700 lb.	$6.00 per lb.	$10,000.00
Prints	325,000 lb.	0	0	0
Parcels	220,000 lb.	2,200 lb.	$1.00 per lb.	$ 2,200.00
Total		3,900 lb.		$12,200.00

On a basis of three trips each way per week initially, the capacity of the aircraft would need to be about 1,500 lb. of pay load and the gross revenue would be about $4,000 per trip.

If passengers are to be carried, the figures indicate that about one-sixth of the total passengers travel first class, or about 1,000 per week each way. If 2½ per cent of these travel by air, the number will be 25 per week or, with three trips per week, about 8-10 per trip, yielding a revenue, at the suggested fare, of about $4,000 per trip.

FLIGHT SCHEDULE

In drafting the flight time-table, many factors must receive consideration, only a few of which will be mentioned here.

The nature of competitive services may largely determine the terminal to terminal time permissible. In this case, with competition confined to fast liners and airships, adequate time advantage will result from a twenty-four to thirty-hour service.

An important factor is the requirement of the traffic. Contemplating mail and express traffic only, times of arrival and departure should be arranged to permit collection and delivery of mail to suit business hours.

Connections with existing services must also be provided for in arranging the schedule.

Difference in time, on a long east-west service such as this, must not be overlooked.

The service being new and experience lacking, proper allowance must be made in the flight schedule for uncertainties and contingencies.

Initially, the schedule must be arranged to make operation as easy as possible for the personnel. The schedule should not be too close to the limit of which the aircraft are capable. The added strain, due to excessive haste and undue emphasis on the maintenance of schedule, may lead to personnel taking unnecessary risks and inevitably to disaster, as has been recently demonstrated.

As take-off is generally easier than landing at night or under conditions of poor visibility, particularly with catapulting, departures should be scheduled at night to permit landing after the oversea flight in daylight.

A suggested schedule is as follows:

Westbound

London—depart 8.00 p.m., permitting collection of mail at close of business day.

Limerick—depart 12.00 midnight.

Botwood, Nfld.—arrive 11.00 a.m., Atlantic Standard time, allowing fifteen hours for flight against headwinds.

Montreal—arrive 5.00 p.m., Eastern Standard time, permitting carriage of mail to many Canadian and United States points overnight, for delivery in morning.

Elapsed time—twenty-six hours.

Eastbound

Montreal—depart 2.00 p.m., Eastern Standard time, permitting collection of mail at noon.

Botwood, Nfld.—depart 10.00 p.m., Atlantic Standard time.

Limerick—arrive 4.00 p.m., allowing fourteen hours for flight with following wind.

London—arrive 8.00 p.m., permitting distribution of mail, during the night, to many European points, for delivery in the morning.

Elapsed time—twenty-five hours.

This schedule, based on a cruising speed on the ocean crossing of not less than 180 m.p.h. and providing fourteen and fifteen hours for the crossing, allows ample margin for head winds and deviations to take advantage of weather conditions.

With a tri-weekly service initially, the east and west flights would be made on alternate days.

THE TERMINALS

The bulk of the North Atlantic traffic is between ports in the British Isles and those adjacent to or reached through the English Channel, and Canadian and North Atlantic ports of the United States. In other words, the heaviest traffic flow is between ports serving the thickly populated and industrial region of Europe and ports serving the corresponding region of North America.

Hence, a transatlantic air service, to carry that portion of the inter-continental traffic demanding speed should operate between terminals convenient to these regions and should ultimately, taking full advantage of the freedom of aircraft, follow the shortest and most direct route between these terminals.

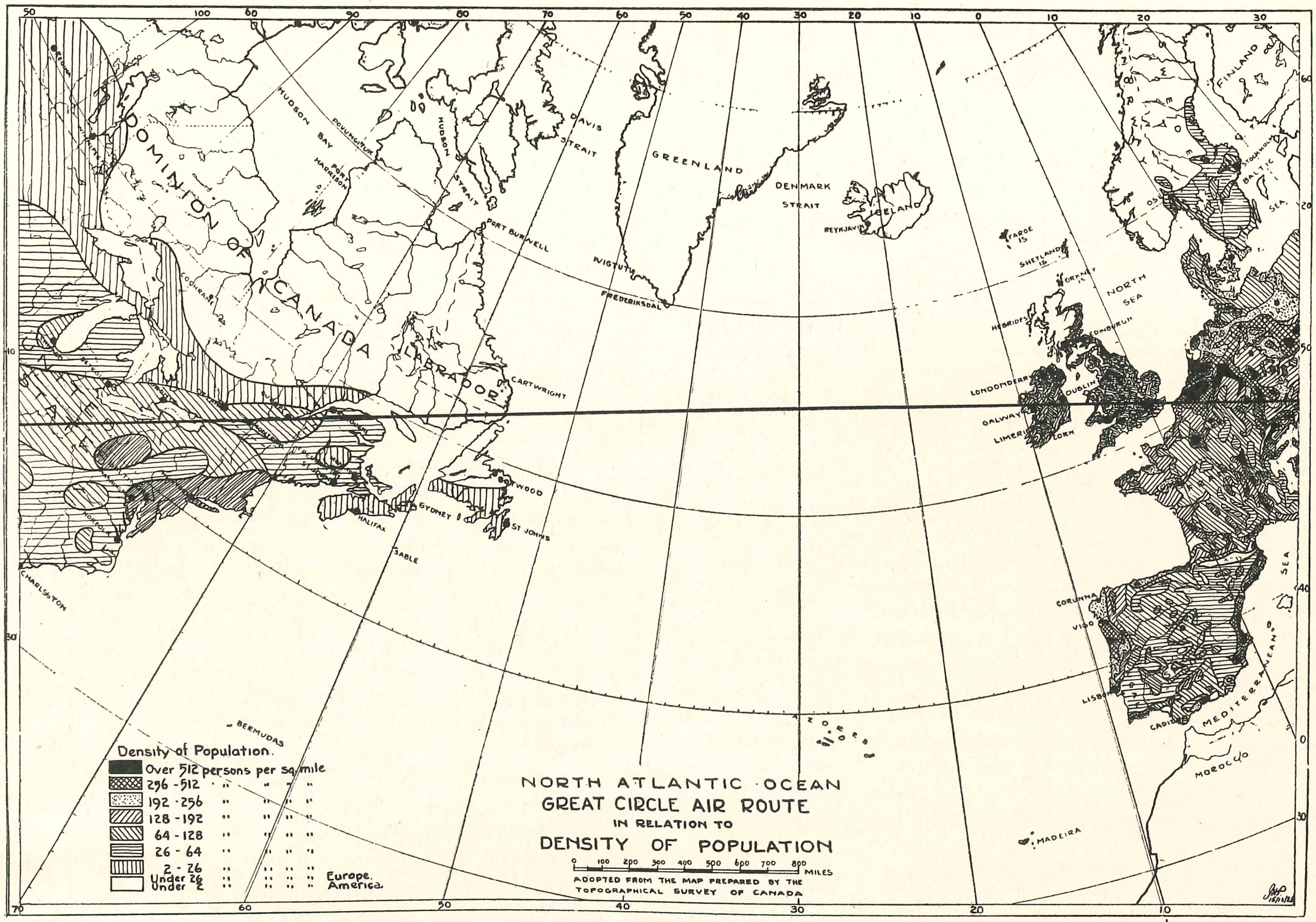


Fig. 6—Great Circle Air Route in relation to Density of Population.

The map of Fig. 6, showing density of population, indicates that London is well situated to serve as a distribution point for overseas traffic to the industrial region of Europe and possesses the advantage that it is now the focus of a system of air lines radiating to all parts of Europe. Having due regard for national considerations in the choice of the terminal, it also appears from the map that Montreal is favourably located to serve as the western terminus and centre of distribution for the industrial areas of Canada and of the United States.

The Route

The ultimate route of the inter-continental air service should therefore be the great circle, between these terminals and the prior routes, established during the development period, should approach the great circle as closely as the capabilities of aircraft at the time permit limitations of range, weather and topography to be overcome.

The courses flown and the air routes proposed across the North Atlantic have been selected generally to circumvent the length of the non-stop oversea flight and to take advantage of favourable or avoid unfavourable weather, or for both reasons. Most successful aeroplane crossings eastward have been from or by way of Newfoundland to take advantage of the short sea crossing and favourable winds and, in the case of flights from the United States, the opportunity, afforded by the long coast flight, to check instruments and motor. All early flights were made in the least stormy season of the year and few, if any, flights have been made starting irrespective of weather conditions. In Fig. 1, are plotted the courses of a number of the more important flights that have been made.

The air routes flown or proposed may be broadly classed as northern, southern and direct.

The northern or Arctic routes are by way of Iceland and Greenland. The most practical of these routes is probably the following (see Fig. 7): London-605[11]-Shetland islands (or Orkney islands)-220–Faroe islands-485-Reykjavik, Iceland-780-Frederiksdal, Greenland-630-Cartwright, Labrador-630-Shediac, N.B.-435-Montreal.

Since the navigation of the North Atlantic was first studied on a scientific basis by Maury early in the nineteenth century, there has been a tendency to recommend shipping routes farther and farther south, despite their great length, to avoid icebergs, fog and storms.

Similarly, the southern air routes, flown or proposed, and based on the Azores, have been selected, not so much to reduce the length of the overseas flight, since little, if anything, is gained in this respect, as to take advantage of more favourable weather conditions.

The southern routes are:

1. That by way of the Azores and Bermuda, recommended by the Hydrographic Office of the U.S. Navy Department (Pilot Chart of the Upper Air—North Atlantic ocean) and partially flown by the Graf Zeppelin in October, 1928. From London to Montreal, this route would be: London-290-Brest-400-Corunna-320-Lisbon-1,050-Horta, Azores-2,050-Bermuda-800-New York-340-Montreal.

   The U.S. Hydrographic Office also recommended routes from the Azores to Cadiz, Brest and Plymouth. Corunna is also a possible European landing point from the Azores and Norfolk and Baltimore alternative points of landing from Bermuda.

[11]Distances are approximate and in English miles.

2. That direct to New York from the Azores, roughly following the New York-Mediterranean steamer lanes, a distance of 2,370 miles.
3. There is also the intermediate route by way of the Azores and Newfoundland, followed on the first Atlantic crossing in 1919 and on several flights since. This route is Lisbon-1,050-Horta, Azores-1,350-St. Johns, Nfld.-355-Sydney, N.S.-660-Montreal.
4. To take advantage of the better weather conditions there existing, routes still further south have been suggested (Verle and Viant 1927, Bleriot 1927). The following commercial route was recently proposed by Musella[12]:—Lisbon (Cadiz in winter)-600-Madeira-1,430-28-0-0 N., 40-0-0 W.-920 (via 28th parallel)-28-0-0 N., 55-0-0 W.-660-Bermuda-800-New York.

Some flights have been made between Europe and North America by way of Africa, the South Atlantic and South America.

The great circle route between London and Montreal crosses Ireland and Newfoundland and passes down the St. Lawrence valley. The approximate length is 3,250 miles. This route is the shortest and therefore the fastest and the land to land distance compares very favourably with that along other practicable routes.

For reasons already mentioned, most transatlantic flights by aeroplane have closely approximated the great circle route.

The great circle route is the commercial air route to be ultimately used when the development of aircraft permits. Immediate complete utilization, non-stop, of the route is impracticable owing to the present limited long range carrying capacity of aircraft which necessitates intermediate landings and imposes limitations on the choice of the location of the intermediate airports. In addition, for the present at least, it is desirable that the transatlantic route connect with and utilize the trans-Canada airway.

To meet these restrictions, intermediate bases in Ireland and Newfoundland must be utilized and the probable route of the air service planned to be inaugurated in 1937 is London-70-Southampton-340-Limerick, Ireland,-2,010-Botwood, Nfld.-470-Shediac, N.B.-435 (via trans-Canada airway)-Montreal.

This route deviates but little from the great circle and its length, 3,325 miles, is consequently little greater than the 3,250 miles of the great circle. At the same time, the length of the oversea flight is practically the same as for the great circle.

The most suitable of the foregoing routes is the one which best permits the requirements of the service—reliability, speed, regularity, frequency and economy—to be met. With the limitations of present day aircraft, all of these requirements will be influenced to a greater or less degree by the length, overall and oversea, and climatic conditions. However, while possible, it is improbable that weather conditions along a shorter transatlantic route would be so much more difficult as to necessitate heavier, slower and more costly aircraft, requiring a longer time for the route than would the lighter, faster and less expensive machines permitted by the more favourable weather of a longer route.

The figures of Table II emphasize the advantage of the great circle route and routes approximating it with respect to overall length. From this standpoint, the northern route is superior to the Azores routes. The shortest of the latter is 30 per cent, or over 1,000 miles longer than

[12]Aeronautica 12, 1932, pp. 1024-37.

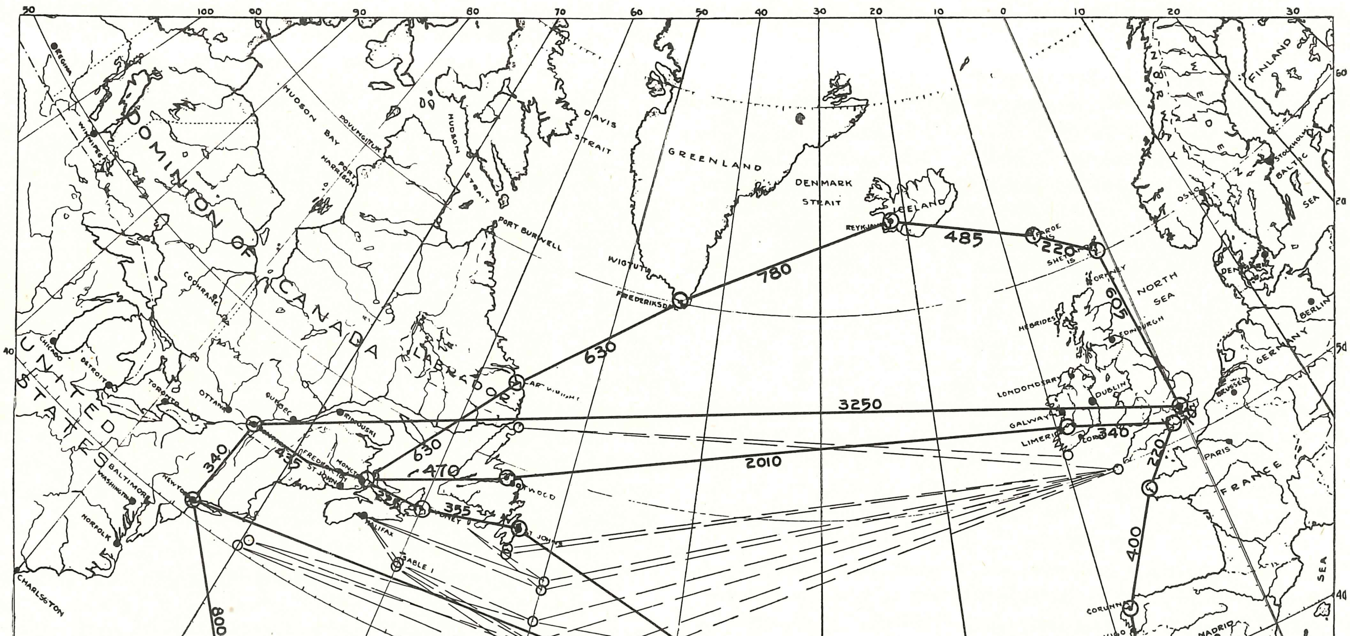


Fig. 7—Air Routes.

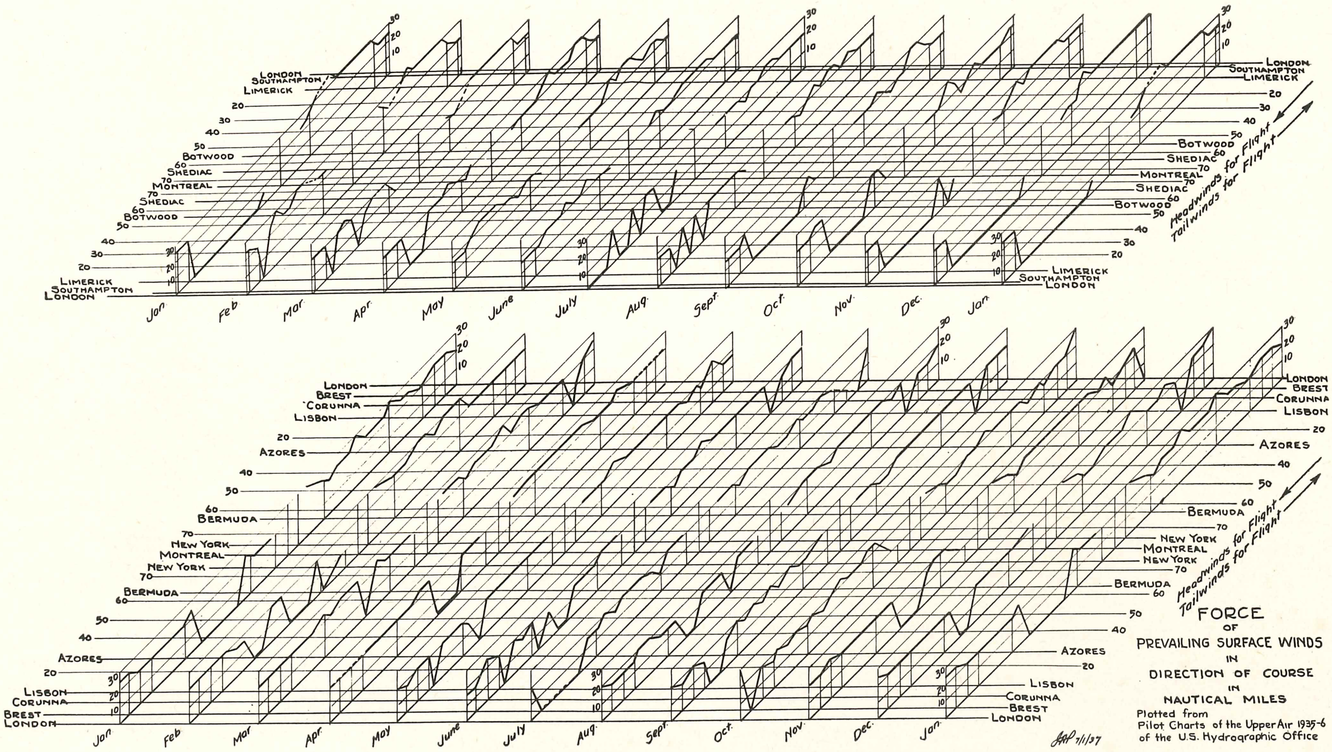


Fig.8 —Force of Prevailing Surface Winds.

the proposed direct route. The overall length of the route, in its bearing on the time from terminal to terminal, is a highly important factor, in view of the keen competition to be met from modern transatlantic steamships and airships.

TABLE II

COMPARISON OF ROUTES—LONDON-MONTREAL

Route	Overall length miles	Maximum oversea distance miles
Northern		
By way of Iceland-Greenland-Labrador.....	3,785	780
Southern		
1. By way of Azores and Bermuda.........	5,250	2,050
2. By way of Azores and Mediterranean steamer lane.........................	4,770	2,370
3. By way of Azores and Newfoundland....	4,425	1,350
4. By way of Madeira and Bermuda........	5,760	3,610
Direct		
1. Great circle...........................	3,250	1,870
2. By way of Limerick and Botwood........	3,325	1,900

While the longest oversea flight of the Arctic route is much shorter than that of any of the others (unless artificial aids are used), it is considered otherwise impracticable for reasons to be given. The 1,350 mile oversea flight between the Azores and Newfoundland is shorter than the 1,900 mile Ireland-Newfoundland flight, but the former route is 30 per cent longer than the latter and will be seen to possess little if any advantage from a weather standpoint. Any advantage possessed by the Madeira route is more than offset by its much greater length and the long oversea flight, and the Azores-Bermuda route suffers from the same disadvantages to a lesser extent.

Thus, on a basis of overall length, the direct route possesses marked superiority, while its inferiority in respect to length of oversea flight, as compared with two of the routes, is more than offset by its superiority in other important respects.

THE WEATHER

Comparison of the different routes from the standpoint of weather will be confined to two only, the direct and the southern, by way of the Azores and Bermuda, for the following reasons:

Northern, or Arctic routes, have been flown a number of times (see Fig. 1). From the experience of these flights and other available information, it is concluded that these routes, despite the shortness of the oversea flights, are impracticable for regular commercial operation, certainly, in the near future. The disadvantages of the northern routes were dealt with at some length in a previous paper.[13] Such further information as has become available confirms the original conclusion as to the impracticability of the routes. Briefly summarized, the disadvantages of the routes are:

1. Length. The routes lie far from the great circle connecting the thickly populated industrial regions. They are therefore much longer and the resulting greater time between terminals nullifies the principal advantage of air transport, namely, speed.
2. Lack of meteorological information and services (including ships as a source of weather reports) and of reliable charts and maps.
3. Climatic conditions including radio and magnetic difficulties.[14]
4. Difficulties of terrain.
5. Difficulty and cost of establishing and maintaining the necessary ground facilities.

The principal disadvantage of the extreme southern routes is their great length. While the weather is possibly

[13]Transatlantic Air Transport, The Engineering Journal, June 1935, p. 305.

[14]In addition to those mentioned in the previous paper, these conditions include Arctic fog and ice (Amundsen-Ellsworth-Nobile expedition 1936) frequent fog off east coast of Iceland and off the Labrador coast and summer fog south of Cape Farewell.

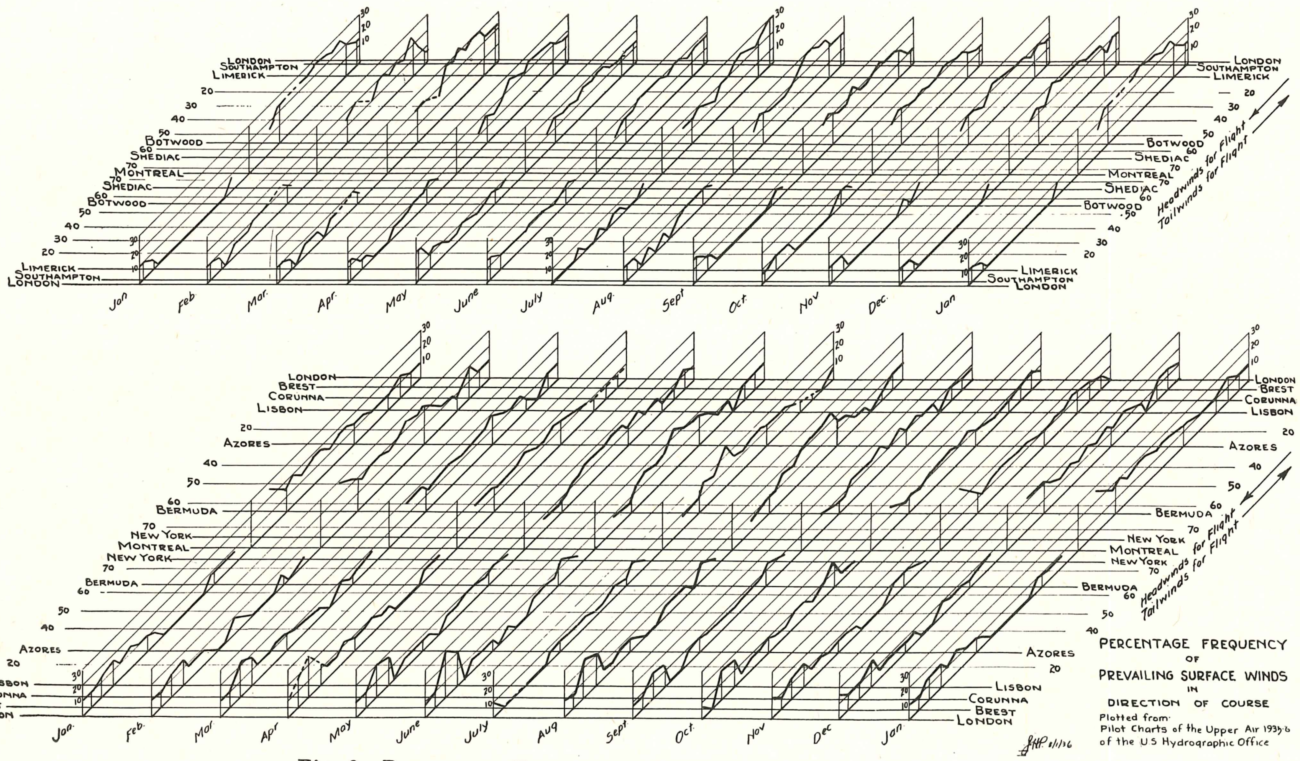


Fig. 9—Percentage Frequency of Prevailing Surface Winds.

generally more favourable, there is the hazard of violent tropical storms. These storms are difficult or impossible to predict due to the lack of shipping in and to the south of the region. The length of the oversea flight is generally large.

The route from the Azores direct to New York possesses no advantage from a weather standpoint over the Azores-Bermuda route and the length of the oversea flight is formidable at present. It is somewhat shorter than the Bermuda route, but it is 1,200 miles longer than the direct route. There is the advantage of the presence of shipping since it lies near the steamer lanes.

The one advantage of the Azores-Newfoundland route is the short oversea flight. Otherwise it is long and experiences much the same weather as the direct route. Indeed it traverses the region of greatest fog frequency southeast of Newfoundland (see Fig. 4).

A brief comparison of the weather of the two remaining routes, the direct and the southern by way of the Azores and Bermuda, follows:

Headwinds

The strength and frequency of surface head and tail winds for the two routes are plotted in Figs. 8 and 9. Lacking information pertaining to upper air conditions over the Atlantic, the routes must be compared on a basis of surface winds and the known variation with altitude over land.

For the direct route, surface headwinds on the westward flight range from 20 to over 30 m.p.h., with a frequency averaging 20-30 per cent and, on the eastward flight, are, for six months, largely zero and for the remainder of the year average 20 m.p.h., with a frequency of about 20 per cent.

Headwinds average generally over 20 m.p.h., with a frequency of 10-20 per cent on the westbound flight over the whole of the southern route except near Lisbon. Eastbound, the headwinds average 20 m.p.h., with a frequency of about 10 per cent except for sections between longitude 40 and 60 W. where the headwinds drop to zero.

On a basis of upper air observations at American coast stations (see Fig. 11), the westerly winds at 10,000 ft. will range from nearly 40 m.p.h. in winter to about 20 m.p.h. in summer and in frequency from 30-20 per cent. The upper air records for European coast stations are less clear. It appears that, at western stations in England, westerly winds range from 20-25 m.p.h. at 5,000 ft. with frequencies from 40-20 per cent. At the latter stations, easterly winds at altitude are more commonly recorded.

While only direct head and tail winds for the courses have been plotted, the effect of cross winds should not be ignored. A wind from any direction in either quadrant to right or left of the direct head wind and even slightly aft of a direct cross wind, in effect, reduces the distance made good per hour. In a general way, along the ocean section of the direct route, winds from N. to W. to S. predominate in strength and frequency, with west winds generally rather stronger and more frequent than others. Except near the coasts, along the ocean section of the southern route, the strength of the different winds, other than E. and possibly SE., is largely the same, with the frequency higher in the western than in the eastern quadrants.

It should also be remembered that, at altitudes over 12,000 ft., winds probably will range only from NW. to WSW.

As head winds become tail winds for flight in the opposite direction, the disadvantage of the one becomes the advantage of the other. However, tail winds assist less than head winds of equal speed retard flight.

The percentage of calms, light airs and variable winds at the surface (see Fig. 10) averages about 5 per cent for the direct route and 10 per cent for the southern route.

To summarize, on the westward crossing, the head winds encountered are up to 10 m.p.h. stronger and of frequency 10 per cent greater on the direct than on the southern route, but this handicap is experienced for 3,250 miles instead of 5,240 miles (or for 1,870 miles of open sea crossing instead of 3,900 miles from Lisbon to New York).

Eastbound, the average strength of the head winds is about the same for the two routes, but the frequency

is less for the southern route. However, the sections experiencing no head winds when eastbound are longer and this condition extends over a greater part of the year on the direct route than on the southern route. Here again the additional 2,000 miles of the southern route must be considered.

In view of the foregoing, the adverse effects of head winds should, on the whole, be more serious for the southern route.

Storms

The direct route lies wholly within the region characterized by cyclonic storms (see Fig. 2) and the storm tracks largely follow the route. The ocean section of the southern route between Portugal and longitude 20 W. lies wholly outside the cyclonic storm area. The leg between Bermuda and New York crosses the storm corridor up the Atlantic coast. Between longitude 20 and 40 W., the route passes the region subject to occasional but intense tropical storms. Local thunderstorms are also prevalent along the route.

From Fig. 10, it will be apparent that the percentage of days on which winds of gale force and over may be expected ranges, for the direct route, from an average of 1 or 2 per cent in summer, to over 10 per cent in winter, the frequency being highest for the section from the Irish coast to longitude 40 deg. W. where it may reach 15 per cent. The gale frequency is zero for much of the southern route in summer and averages less than 5 per cent in winter. The frequency is highest for the sections in the neighbourhood of longitude 50 deg. W. and of New York and may exceed 10 per cent in these regions.

Thus, along the direct route, the storm frequency is high. Storms are also frequent near the coasts, and particularly the American coast, on the southern route and a section of this route is subject to tropical storms.

The handicap imposed by storms will depend on the height to which they extend. Should cyclonic storms be found to extend no higher than 10-12,000 ft., the handicap will not be serious.

Visibility

Fogs—Figure 12 clearly indicates that fogs are much more prevalent along the direct route than along the southern in spite of the fact that the route passes to the north of the worst fog area (Fig. 4). The southern route is practically free of fog except near the coasts. In the vicinity of New York, fog frequency may be as high as 20 percent and the Corunna-Brest-London section, particularly the northern portion, is foggy.

The fogs off Newfoundland are dense and frequent, but seldom, even in the south, surmount the cliffs of the shore and are rarely carried inland. There is often a narrow channel of clear water between the fog bank and the shore. Further north, except in the Strait of Belle Isle, fogs, from a navigation standpoint, are no more serious than in other regions.

Lighthouse records show that fogs are frequent on the east and south coasts of Newfoundland, particularly to the southeast, but the frequency never exceeds 35 per cent and is generally much less (see Appendix VI, Table IIa). The west coast is relatively free of fog. The maximum frequency at points on the west coast may be as low as 2 per cent for the worst month. Sunshine is said to be above the average in Newfoundland and precipitation not large and, while reports conflict as to the degree of prevalence of fog, the foregoing records support the conclusion that there are many fog free areas on the west coast and probably in the interior.

Records (see Appendix VI, Table I) indicate that the frequency of fogs in the St. Lawrence valley is small and less than in the region around New York and portions of the European coast area traversed by the southern route.

As the graphs indicate, little actual fog forms at the Azores. However, strato-cumulus clouds often descend and

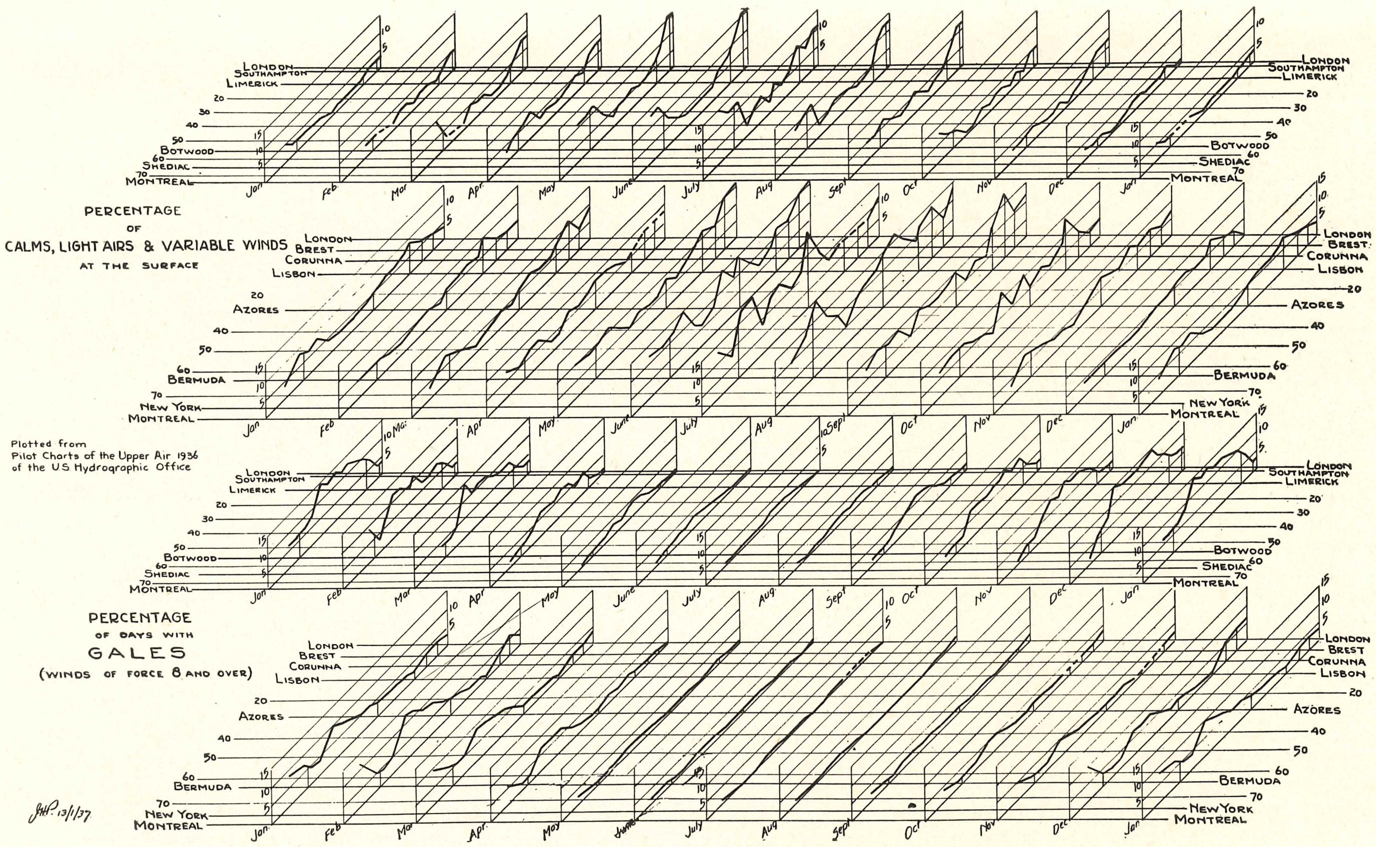


Fig. 10—Percentage of Calms, Light Airs, Variable Winds and Gales.

cover the entire mountainous parts of the islands, rendering them invisible from outside, and even descend to sea level. This occurs principally in June and represents the only lasting "fogs" of the Azores.[15]

Clouds—While the region traversed by the direct route is more generally overcast than that of the southern route, the handicap which this greater cloudiness may impose on the direct route will depend upon the height to which the clouds extend and the efficiency of the blind flying equipment.

Temperatures

Sea and air surface temperatures along the ocean sections of the two routes throughout the year are plotted in Fig. 12. Generally, sea and air temperatures show the same variations. Air temperatures are higher in summer and lower in winter than sea temperatures for the direct route and are generally lower for the southern route except during May, June and July. Along the direct route, the air temperatures increase from west to east by as much as 10 deg. in winter and 5 deg. in summer. On the southern route, the maximum air temperatures are in the region of longitude 40 deg. W. with a slight gradient to the European coast and Bermuda. A steep gradient of as much as 10 deg. in winter occurs between Bermuda and New York.

For the direct route, temperatures average over 50 deg. in summer and under 40 deg. in winter and, along the southern route, the corresponding average temperatures are nearly 70 and about 50 deg.

[15]According to Director of Meteorological Service of the Azores at Angra.

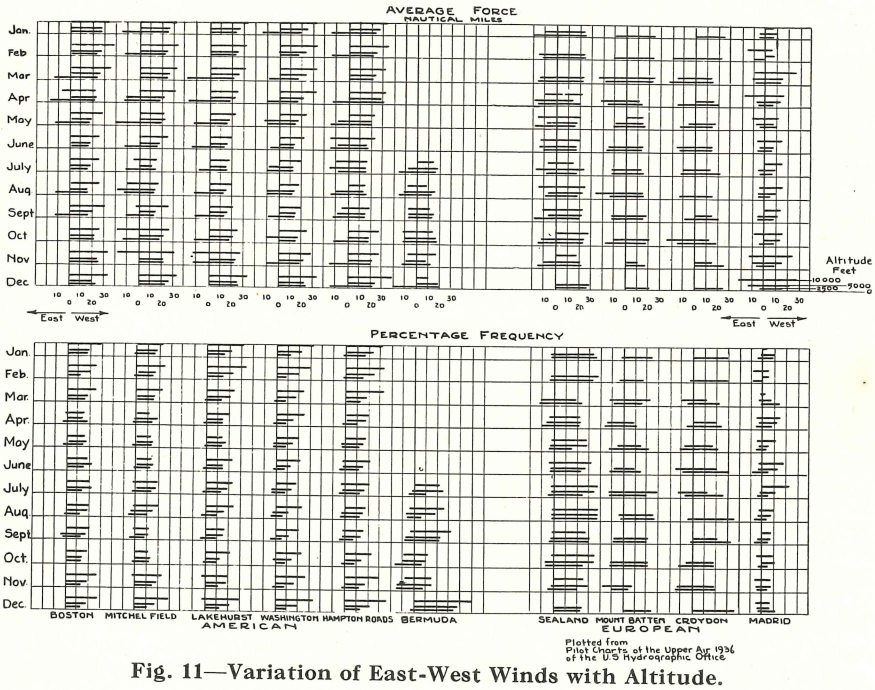


Fig. 11—Variation of East-West Winds with Altitude.

Weather Information

Reports from ships at sea on the regular steamer lanes to the south of the route and from Canadian and United States stations enable the surface weather along the direct route to be reasonably well forecast, since the weather of this area is generally "made" to the west and south. Numerous reports and hence good coverage results from the density of shipping along the New York-English Channel lanes.

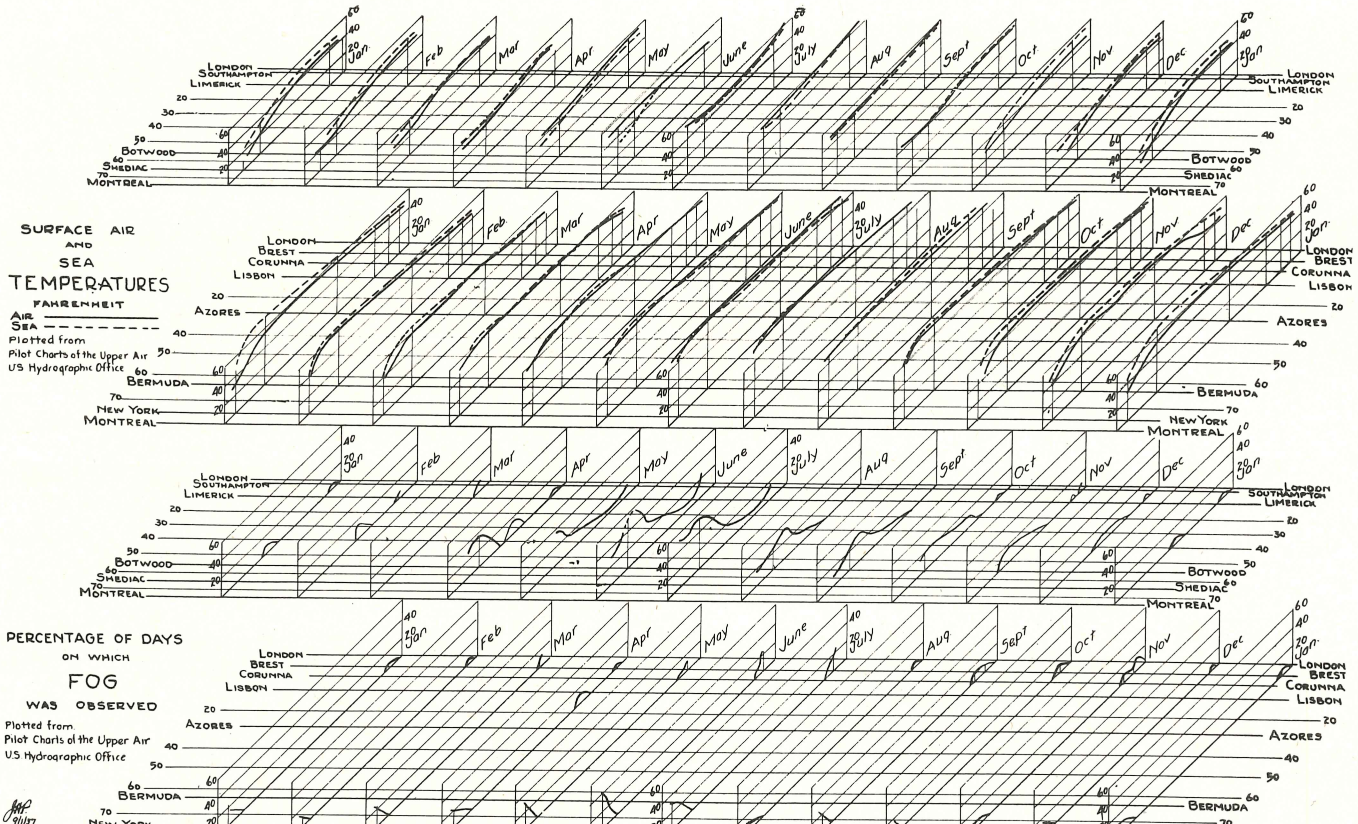


Fig. 12—Surface Air and Sea Temperatures—Percentage Days with Fog.

The European coast section of the southern route, the section between the European coast and the Azores, and that between Bermuda and the coast of the United States are satisfactorily served by reports from ships. There is little shipping, however, between Bermuda and the Azores and still less south of this line and it is in this region that the tropical cyclones originate. Forecasting for this section, nearly 50 per cent of the whole route, is therefore unsatisfactory.

Summary

On the whole, it is concluded from the foregoing that the southern route, from a weather standpoint, possesses but slight superiority over the direct route. Because of the improvement in blind flying and landing equipment, services and technique, lack of visibility due to fog and cloud is no longer a serious handicap and blind flying is inevitable in the operation of a regular and frequent service. It is not improbable that, in the near future, if not now, fog will be of less menace to aircraft than to ships. Also, the real meteorological hazard, that due to the formation of atmospheric ice, while it may be found to be more frequent on the direct route, has already been encountered in the south.

Terrain

The southern route is based on the Azores and Bermuda, the former about 850 miles off Portugal and the latter nearly 700 miles from the North American coast.

The Azores, or Western Isles, belonging to Portugal, are (see Fig. 13) a scattered archipelago of some nine small mountainous islands which rise sharply from their scree covered shores. The volcanic peak of Pico, rising to 7,821 feet, is the highest. There is said to be no suitable base for flying boats in the islands. Of the three principal ports, Angra, Ponta Delgada and Horta, the latter is the only one worth considering for aircraft and its effective size is smaller than charts indicate, due to silting.[16] While adequate for ordinary landings, a long take-off run would extend out into the open sea. Considerable expenditure would be necessary to make it a good harbour. Some dredging was

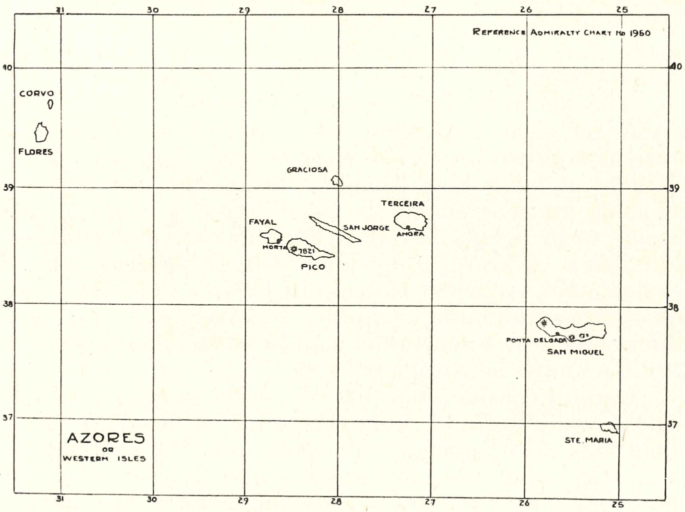


Fig. 13—The Azores.

recently done. The inland lakes, surrounded by mountains, are unsuitable for use by large flying boats. The largest lake, Sete Cidades, on San Miguel, the crater of an extinct volcano, is some 10 miles in circumference, and of irregular shape. There is a small landing field on a plateau on the island of Terceira and it was recently reported that the

[16]The Lockheed Sirius of Colonel Lindbergh was unable to take off here, fully loaded, in November 1933. It was used by the Italian flight on the return from Chicago in the same year.

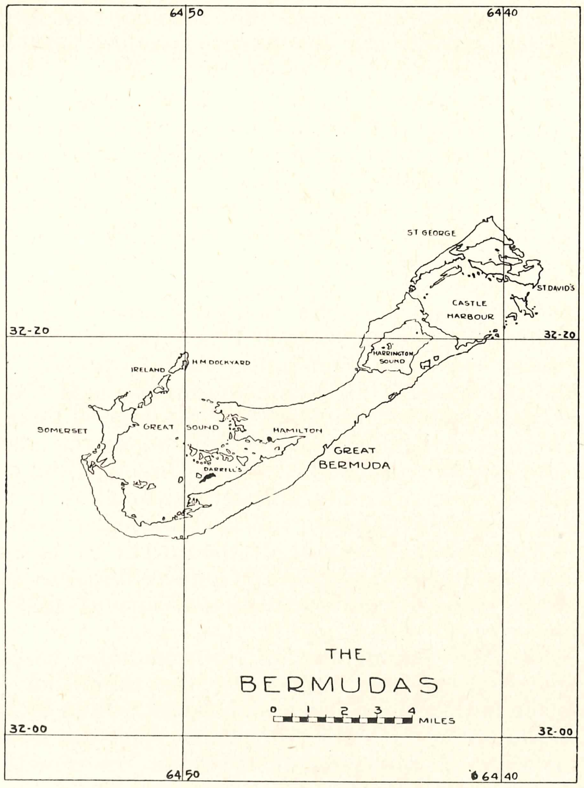


Fig. 14—The Bermudas.

French had selected this site as capable of enlargement, at small cost, into an aerodrome for a transatlantic service.

Because of their exposed position, winds from the W. and SW. render navigation dangerous about the islands. Intense squalls in the vicinity frequently cause tide races, the "houle," to sweep about the islands. Under these circumstances, in spite of the fact that the sea is quite calm during part of the year, lacking harbours, the alighting and take-off of large seaplanes would often be hazardous and regularity of services difficult to maintain.

The Bermudas (Fig. 14) comprise a compact group of some 150 sandstone and coral islands, mostly small islets, on a submarine bank and surrounded by a reef of coral covered sandstone. The sandstone of the islands forms irregular hills, some 200 to 250 ft. in height. The group is some 15 miles long and 5 miles in extreme width and encloses several large and well protected harbours. Darrell's island in the Great Sound is being equipped as a base for a Bermuda-New York air service.

The Bermudas are a British possession and the site of a naval station.

In Europe, the southern route, using the stages London-Brest-Corunna-Lisbon involves landings in French, Spanish, and Portuguese territory and, in America, a landing in and flight over United States territory.

The direct route will use bases in Ireland and Newfoundland. Among the many fine natural harbours of Ireland, there are several well suited for air bases. The north and west coasts are high and rocky—those of the east and south less so. The more mountainous areas are in the north and south and the central plain extends, in places, to the east and west coasts.

Promising sites for combined sea and land bases appear to include (see Fig. 15), on the north coast, Lough Foyle, near Londonderry (used by the Italian flight in 1933), on the west coast, Galway Bay and the estuary of the Shannon, and Cork Harbour on the south coast.

There are high hills (2,000 ft.) west of Lough Foyle. Between Galway Bay and the Shannon estuary, the country is relatively low, few peaks exceeding 1,000 ft. and there is a large percentage of low land. The excellence of Cork Harbour is well known. There is much sheltered water in the reaches of the harbour and many sites suitable for the construction of airports. The surrounding country is low, but the highest hills in Ireland (3,500 ft.) lie between Cork and the west coast. As indicated in the previous paper already referred to, Galway Bay and the Shannon estuary appear most suitable.

The rugged and rocky coast of Newfoundland, with high and perpendicular cliffs in most places and deep water to the edges, is heavily indented (see Fig. 5). There are many large bays and numerous islands, especially on the east and south coasts. The hills are mainly near the coasts and average 1,500 ft. in height. The highest mountains are in a range extending some 200 miles along the northwest coast and rise to over 2,200 ft. almost directly from the sea.

The interior is mainly undulating, much of it heavily wooded, in which there are innumerable lakes and rivers.

In view of the foregoing, it should not be as difficult, as is often assumed, to find ice and fog free harbours suitable for marine bases, or quite satisfactory airport sites in the interior.

From the standpoint of intermediate bases, the southern route is handicapped by the conditions in the Azores, on which the route is dependent, while in Ireland and Newfoundland, on the other hand, there are numerous suitable sites for intermediate bases for the direct route.

The Better Route

It is concluded from the foregoing brief comparison of the two routes on a basis of length, weather and terrain, that, while some advantage rests with the southern route from the standpoint of weather, the advantage is insufficient to compensate for its much greater overall length, the greater length of oversea flight and the difficulty respecting provision of a suitable base in the Azores and hence, on the whole, the direct route is the better.

Fig. 15—Ireland.

It has been suggested that the direct route should be used in summer and the southern route in winter. Admittedly, the climatic conditions are, in some respects, more severe over the former in winter, but here again the decision is the fundamental one as between weather and length and terrain. In the author's opinion, the direct route is superior, even for winter operation.

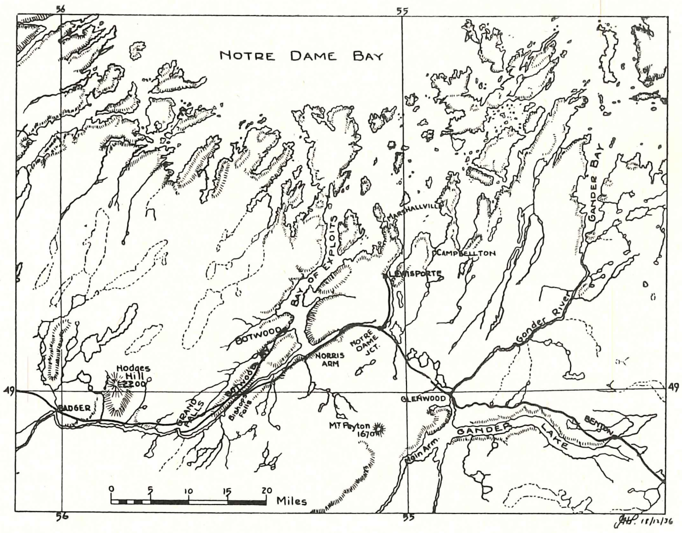


Fig. 16—Botwood and Vicinity.

The trans-atlantic service between London and Montreal will be an important part of the network of airlines connecting the various units of the British Empire and, as part of the Empire network, the desirability that the service should be "all-red" is obvious.

ORGANIZATION OF THE DIRECT ROUTE

Selection of Intermediate Refueling Bases

Until experience has indicated the most suitable type of aircraft for the service, provision should be made for both landplanes and seaplanes at the terminals and intermediate stations. There is also the possibility that aircraft of both types may continue to be used in the service.

The selection of the particular route to be followed, within the zone of the great circle and of the intermediate stations between terminals, is governed by many factors. Initially, to shorten as much as possible the oversea flight, refueling stations should be established as near as practicable to the west coast of Ireland and east coast of Newfoundland. Nature of terrain, such as adequate area of level ground, sufficient expanse of ice-free sheltered water, low-lying surrounding country, together with the usual requirements as to nature of soil, drainage, access (railroad facilities) must be considered.

Careful consideration has also to be given to meteorological conditions and, from this point of view, fog and ice conditions are important. Ice-free water is necessary for year-round operation of seaplanes and, in Newfoundland, this probably eliminates the use of lakes in the interior.

The relation of the proposed route to existing or projected air services and to other transportation systems must receive attention.

It is obvious that the particular route and sites of stations can only be decided upon after detailed information concerning these various factors has been secured and studied and with full knowledge of the relative importance of the different economic and political considerations involved.

As previously indicated, the reported route of the service planned for inauguration in 1937 is London-South-

ampton - (Portsmouth) - Limerick - Botwood - Shediac(?)-Montreal.

Portsmouth is contemplated as the marine terminus of the main Empire Air Routes. Temporarily, Hythe or Southampton Water, where slipway and hangar facilities exist, is in use (December, 1936) as a flying boat base for the India service and will be used for the Atlantic service. Langstone Harbour, adjacent to Portsmouth, will probably be made the permanent base. It is said to be fog-free and, by means of barrages across the entrance, or by dredging channels, an excellent marine base can be provided and there are suitable areas available for an aerodrome. A railroad runs close by and the site is close to Southampton, with its many facilities and rail connections to London.

The site of the combined marine and land base, to be named Kilconry, reported being prepared in Ireland, is at Rynanna Point, in County Clare, at the junction of the River Fergus with the Shannon, about halfway between Limerick and the coast. The Shannon is here some eight miles wide and the surrounding land is flat. A temporary base will be at Foynes, County Limerick, on the south shore of the Shannon and permanent wireless stations will be located in the village and on Foynes island in the river.

In Newfoundland, based on the results of special meteorological investigations, both surface and upper air, carried on since 1934, two sites have been selected and are in preparation. Port Botwood, a port near the mouth of the Exploits river (see Fig. 16), chosen as the marine base, is now used for the shipment of pulp and paper and is connected by a branch railroad with the mills at Grand Falls and the main line of the narrow gauge Newfoundland railroad. The river at Botwood is about a mile wide and the harbour is reported to be fog-free and satisfactory for flying boats.[17]

As the topography of the surrounding country is not suitable for the construction of an aerodrome, the site selected for the Newfoundland airport is at Hatties Camp, north of Gander Lake and south of the railroad, some 42 miles east of Botwood and about 30 miles from the east coast where an ample area is available, requiring little levelling and with good drainage. The elevation is 500 ft. above sea level. Clearing and grading started in 1936. Four concrete and tar macadam runways, intersecting at 45 deg., are to be constructed, each 1,500 by 200 yd., and with a load capacity of 5 tons per sq. ft. The main runway, equipped for blind landings, runs NE.-SW. and is to be 1,600 by 400 yd.

In Canada, there are several possible sites for the terminal of the route from Newfoundland, including Shediac, Moncton and Saint John in New Brunswick and Sydney or Louisburg in Nova Scotia. Although no decision will likely be made until after trial flights, Shediac appears to be the preferable site. It possesses adequate facilities for manoeuvering large flying boats and is close to Moncton (which lacks such facilities), on the trans-Canada airway. Shediac was used by the Italian flight in 1933.

The Fuel Load Handicap in Long Range Flight

Unlike other means of transport, the engines of heavier-than-air aircraft must not only supply the power for propulsion, but also for the support of the aircraft and its load. In consequence, the horsepower required and the fuel consumption are higher for a given payload than for transport in which the weight is supported directly by the earth or by displacement.

The limitation imposed on the payload by the large load of fuel that must be carried for the transatlantic flight is illustrated by the figures of Table III derived from a simple approximate calculation. The magnitute of the necessary fuel load, the possible payload (neglecting weight

[17]Colonel Lindbergh refueled his Lockheed Sirius here in 1933.

Table III

Payload Capacity

Assumptions:—Distance 1,800 miles, 30 m.p.h., head wind, cruising power 2/3 rated power, cruising fuel consumption 0.6 lb. per hp. per hr.
W = gross weight of aircraft.

	Weight ratio*—1.75			Weight ratio*—2.00			Weight ratio*—2.25		
Power loading†	10	15	20	10	15	20	10	15	20
Range—Hours									
	10.7	16.1	21.4	12.5	19.0	25.0	14.0	21.0	28.0
Fuel Load									
Cruising speed m.p.h.—120	0.80W	0.53W	0.40W	0.80W	0.53W	0.40W	0.80W	0.53W	0.40W
150	0.60W	0.40W	0.30W	0.60W	0.40W	0.30W	0.80W	0.40W	0.30W
180	0.48W	0.32W	0.24W	0.48W	0.32W	0.24W	0.48W	0.32W	0.24W
Pay Load Carried—Pounds									
120	0	0	0.03W	0	0	0.10W	0	0.02W	0.15W
150	0	0.03W	0.13W	0	0.10W	0.20W	0	0.15W	0.25W
180	0	0.11W	0.19W	0.02W	0.18W	0.26W	0.07W	0.24W	0.32W
Pay Load Carried—Pounds per Horsepower									
120	0	0	0.6	0	0	2.0	0	0.3	3.1
150	0	0.5	2.5	0	1.5	4.0	0	2.3	5.1
180	0	1.7	3.8	0.2	2.7	5.2	0.7	3.6	6.4

*Weight ratio $= \dfrac{\text{gross weight}}{\text{net weight}}$ †Power loading $= \dfrac{\text{gross weight}}{\text{total rated power}}$

of crew, etc.) and the influence thereon of structural weight, power loading and cruising speed are shown.

With an aircraft of normal design, in which, for a long non-stop flight, the weight of fuel leaves a very small part of the disposable load available for pay load, the desired pay load capacity can be attained, within certain limits, by increasing the size of the aircraft until the fraction of the disposable load available equals the desired pay load. This procedure is obviously uneconomical. The alternatives are mid-ocean refueling, fueling in the air or a resort to some form of assisted launching.

Mid-Ocean Refueling

Evidently, if satisfactory refueling facilities could be provided at one or more points in mid-ocean, the fuel load carried could be reduced and the pay load correspondingly increased. Two alternative proposals for mid-ocean refueling have been made, one by the use of ships and the other by the provision of floating islands.

The Deutsche Luft Hansa has employed "depot ships" on the South Atlantic section of its air mail service to South America since 1934 and in the summer of 1936 employed one of these ships in trial flights across the North Atlantic by way of the Azores.

The depot ships of the D.L.H.[18] are each equipped with a compressed air catapult for launching flying boats, a rotating and folding electric crane for lifting the aircraft on board or on the catapult and a trailing apron or "stau-segel" for facilitating the hoisting of aircraft on board in rough weather. The ships also have very complete radio and meteorological equipment.

The depot ship was originally employed as a refueling station in mid-ocean. More recently, having improved the range of the aircraft, the ships have been used for launching the aircraft at each end of the oversea stage. As a refueling station, the aircraft flew to the ship, alighted on the sea,

[18]Details of the depot ships and of the South Atlantic service are given in Appendix VII.

was hoisted aboard, refueled and serviced and launched by catapult for the second stage of the crossing.

The depot ship is mobile, permitting the route to be changed at will, as, for instance, from the direct in summer to the southern in winter. If the aircraft is forced down within reasonable distance (and in fair weather), the ship can proceed to its assistance. The cost of the ship is low, as compared with that of a floating island.

However, as a permanent refueling station, in mid-ocean on a schedule service by the direct route, the depot ship is considered impracticable because of the frequency of gales on the North Atlantic which would render disastrous the alighting of aircraft on the sea.

On the other hand, as a temporary expedient during the initial operation of the service, to serve as a beacon ship and meteorological station, the depot ship possesses attractive possibilities.

Floating islands to serve as refueling stations in mid-ocean have been projected from time to time. Most such schemes were, to use M. Bleriot's description "a little fantastic."

The design to which most careful study and tests have been devoted and which appears the most promising technically is the so-called Armstrong Seadrome, as described in Appendix VIII.

The seadrome is a floating structure, embodying an unobstructed flying deck, with hangar, shop, radio and meteorological facilities and accommodation for crew and passengers. Its design is such that it is claimed to be unaffected by wave action. It is retained in place by special anchoring arrangements.

To provide a flight deck of adequate size for modern high speed, heavily loaded aircraft, the structure must be large and, while possibly technically feasible, the cost will be high and the financial burden on the service excessive.

From the point of view of the direct route, the fundamental obstacle to the use of the seadrome is, that owing to the surface climatic conditions—gales and fog—landing on the restricted deck would be hazardous and often impossible.

It is concluded that the provision of mid-ocean refueling stations on the direct transatlantic route is impracticable.

Fueling in Flight after Take-Off

By having the aircraft take off and climb to its operational height, without its fuel load, and there supplied from another aircraft with the fuel for the journey, the take-off handicap would be overcome.

Many tests of methods of fueling in flight have been made and endurance records have been established by means of numerous refuelings in the air. The operation is, however, one that so far has only been performed in fair weather. In its present stage of development, it is not considered suitable for use in a regular commercial service, the schedule of which must be maintained irrespective of weather conditions.

Take-Off Conditions

The take-off speed and the landing speed may be taken as roughly equal to the stalling speed of the complete aircraft. The latter depends on the maximum lift coefficient of the wing, the air density (altitude of the landing point) and the wing loading. The maximum lift coefficient may be increased by such lift increasing devices as slots and flaps and with good control at low speeds, the landing speed, and to a less extent, the take-off speed, can be correspondingly decreased.

Actual take-off speeds may be 10 per cent higher than minimum flying speeds, to provide a reserve of lift at take-off. At the same time, "ground effect" reduces the landing and take-off speeds.

The power required for take-off is greater than for normal flight. For take-off under full load, in a reasonable distance or time, the maximum permissible take-off power of the engines is usually employed, while for cruising in level flight the engines are throttled to cruising power for which the fuel consumption is a minimum. As the maximum take-off power of the engines may be 110-125 per cent and the cruising power about 66⅔ to 75 per cent of rated power, it is evident that the power used for take-off is about twice that for cruising.

With an unlimited take-off run or time, the take-off power would of course be less.

Additional power over that for cruising is also required for climbing, but this need not be large if there are no high obstacles to be cleared in the vicinity of the stations.

A further consideration is that a margin of power over that required for cruising is necessary to enable the aircraft to remain in flight in the event of failure of one or more engines and to permit the engines to operate at reduced power for low fuel consumption and wear on engine.

The approximate analyses of take-off conditions given in Appendix IX indicates, in a general way, the factors affecting take-off and their relative importance.

Assisted Launching

With assisted launching, by catapult or otherwise, the aircraft for a given long range service will be smaller and of lower power since it can be designed specifically for cruising conditions with very high wing loading and a cruising speed approximating that for maximum aerodynamic efficiency. It is seen, for instance, from the graphs of Fig. 24, that, for a cruising speed of say 160 m.p.h., the pounds of gross weight carried per horsepower at different wing loadings are as follows:

Wing loading	18	28.6	40
Pounds per horsepower	15.0	21.1	26.5

The saving in power and consequent fuel consumption thus affected can be used to increase the payload, the range, or both together, or the original power can be used to carry the same load at a higher speed. In this way, long range and large payload can be combined in the same aircraft.

Assisted launching of heavily loaded aircraft is subject to the condition that a large part of the load must be of a consumable or readily dischargeable nature, in order that the landing speed at the end of the flight may not be excessive and that, in an emergency, a safe landing may be made by jettisoning part of the load.

Even with normal aircraft of high wing loading, able to take off unassisted under prescribed airworthiness requirements, the landing speed may exceed safe limits and require jettisoning of fuel if an emergency develops immediately after take-off.[19] For this reason, one noted designer of flying boats has proposed that aircraft should be licensed for a higher load for take-off than for landing.

In the case of marine aircraft, the displacement of the flotation gear will be that required for conditions at the end of the flight and the hull or floats can therefore be smaller, weigh less and have less drag than that necessary for unassisted take-off.

Catapulting

The launching of aircraft by catapulting is of course not new, since a simple device of this kind was used by the Wright brothers and the system employed in launching gliders is of the same kind.

Naval vessels have long been equipped with aircraft catapults and, as already mentioned, catapults have been employed on liners for launching aircraft in connection with ship-shore air mail services.

It is indicated in Appendix VII that the catapult equipped Deutsche Luft Hansa depot ships now function

[19]Such a situation has occurred on at least one occasion in the case of an aircraft of the type on which the curves of Fig. 24 were based.

as launching stations in the South Atlantic service. From the German standpoint, lacking shore bases, the mobility of the ship is an important consideration. For the operation of a North Atlantic service over the direct route in summer and the southern route in winter, this mobility would also be advantageous, obviating the necessity of duplicate shore launching stations. Further, the use of the depot ship would satisfactorily overcome many of the difficulties arising from conditions in the Azores. But, with a permanent route and fixed stations, the mobility of the depot ship is not necessary.

However, the many catapult launchings that have been made on the D.L.H. South American service without an accident, insofar as is known, do prove that this method of launching heavily loaded aircraft can be safe, reliable and generally satisfactory on a transoceanic air mail service.

The launching of commercial aircraft by means of long run catapults of the car and track type was suggested to the author by Mr. D. S. Atkinson, in January 1935. Similar suggestions have since appeared in the technical press and it is reported that the use of catapults is receiving consideration for the transatlantic service planned for 1937.

The proposal, which is dealt with in some detail in Appendix X, is briefly as follows. The launching runway is a length of track about one-half mile long, laid on land in the direction of the prevailing wind. If for marine aircraft, the track is laid on or near the shore. The car is driven by cable from a fixed prime mover, Diesel or gasoline engines on the car, or by aircraft engines and airscrews. The aircraft cradle is so arranged as to permit the aircraft to align itself with the relative wind. The attachment of the aircraft to the cradle is such that, on attaining a speed in excess of the minimum flying speed, acceleration is reduced to zero and the car speed held constant until the pilot signals and releases the lock. The car then begins to decelerate and the aircraft flies off. After the launch, the car is brought to a stop under the control of the operator.

Launching from an Aircraft in Flight

Many years ago, a glider was dropped from a balloon[20] and more recently aeroplanes have been launched from rigid dirigibles. At the present time, two aircraft are nearing completion which are intended to be used in combination, one being launched from the other.

In this so-called composite aircraft, proposed by Major R. H. Mayo, the two aircraft combined function as a single unit for the take-off and later, at altitude, the one serves virtually as a catapult for launching the other. While the detailed arrangement may be varied to suit different conditions, in the composite aircraft under construction, the upper component to be launched is a high performance, heavily loaded seaplane, mounted on top of the lower component or carrier aircraft, a lightly loaded flying boat of more or less normal design. Locked together, the characteristics of the combination are such that the stalling speed is low and a satisfactory take-off, together with good climb, are possible.

The patents associated with the proposal cover principally the method of effecting separation of the components through the medium of aerodynamic forces. Apparently the aerodynamic characteristics of the wings of the two components differ, due either to a use of different basic sections or to the use of slots and flaps and are so chosen as to ensure the upper component carrying a larger and larger share of the combined weight as the speed increases until at launching speed the upper component is lifting more than its own weight so that when released the two components separate. It is understood that the patents also cover separation through the increasing of the incidence of the upper component during flight.

Apparently during take-off all control rests with the pilot of the lower component, the controls of the upper component being locked in neutral and the pilot virtually a passenger. On reaching the proper height, reported to be 10,000 ft., the aircraft levels off and accelerates to a speed well above the stalling speed of the upper component. At this speed (over 100 m.p.h.) the lower pilot signals his colleague, releases one part of a dual device locking the components together and relinquishes control. The upper pilot assumes control, releases a second part of the locking device and, on the machine reaching a speed corresponding to a predetermined separating force, the locking device automatically releases and permits the components to separate.

After the launch, the service aircraft proceeds on its flight and the carrier returns to its base.

It is obvious that the safety of the launch will depend on excellent co-ordination of controls and infallible working of the locking device and severance of all connections on separation. Further, the stability of the composite aircraft on the water, taking-off and in flight, and of the components during separation will require careful study.

The few constructional and performance particulars of the composite aircraft so far made public, are listed in Appendix XI.

The Composite Aircraft vs Catapult Launching

As compared with the fixed catapult, the following advantages have been claimed for the composite aircraft:

1. *Lower Cost*—The lower component now under construction is reported to be a four-engine boat similar to the Empire boats. While its cost is not known, it is probably not less than the reported cost of the Sikorsky S-42 flying boats, namely $250,000, and a conservative estimate of the cost of the lower component would be $150,000. It is difficult to conceive of a mile long track and launching car and necessary land costing this much.

   The cost of the upper component will be little, if any less, than that of the similar aircraft for catapult launching.

2. *Greater Mobility*—For operation of an air service over a permanent route with fixed bases, mobility is of no advantage.

   For military and naval use, mobility would be distinctly advantageous.

3. *Elimination of Risk Attendant on Launching at Low Height*—Admittedly, this hazard is present with catapult launching, but its magnitude has been exaggerated. With multi-engined aircraft, the danger of all engines cutting out, particularly immediately after launching, when they are presumably in the best of condition, is remote. As indicated in Fig. 28, an aircraft is easily capable of maintaining level flight and climb with a wing loading 40 per cent greater than normal on three out of four engines operating at 75 per cent power.

   With a car and track launching gear, the catapulting speed can be made considerably higher than the stalling speed of the aircraft and, if the latter is held to the car until this speed, on release it will immediately climb.

   Also, the Deutsche Luft Hansa has proved, in three years of regular use on the South Atlantic under much more difficult conditions than those which will obtain in a long-run fixed catapult, that launching by catapult is safe and reliable in commercial service. It remains to be seen whether the separation of the components of the composite aircraft can be as safely effected in flight and at high altitudes.

[20]Montgomery glider dropped from hot air balloon at 4,000 ft. in California, April 1905.

4. *Permits the Use of Fixed Pitch Airscrews*—For unassisted take-off of aircraft with high wing loading and fully supercharged engines, variable pitch airscrews are essential. With the composite aircraft, the heavily loaded upper component, being relieved of most of the burden of take-off, can be fitted with a fixed pitch airscrew, designed for cruising condition, with less sacrifice of efficiency during take-off. There is therefore a saving in weight and cost.
5. *The Aircraft can be Launched at Higher Speed*—A long-run catapult of the type mentioned can launch an aircraft at quite as high a speed for the same expenditure of effort. For the land catapult considered in Appendix X, the maximum power for the car is seen to be from 2,000 to 3,500 hp. for launching a 25-ton aircraft at 100 m.p.h., compared with a reported power of about 3,500 hp. for the carrier component of the composite aircraft to launch a much lighter aircraft at the same speed.
6. *Reduced Cost of Operation and Maintenance*—It is difficult to see wherein these costs will be less than for a long-run catapult. The same handling will be involved in placing the service aeroplane on the car or carrier aircraft and the cost of operation of the carrier may easily exceed that of the car. The economy of the two service aircraft should not be greatly different if a low rate of climb is permissible for the catapult aircraft. In the case of a marine carrier component, depreciation and maintenance will likely be higher than for the catapult.
7. *Ability to Use Small Aerodromes and Harbours*—It is considered that, in this respect, the advantage would rest with the catapult rather than with the composite aircraft. In any case, for operation over a permanent route, such as the one under consideration, with well selected bases, there should be no necessity to use unduly restricted take-off areas.
8. *Ease of Take-Off—Permits Night Take-Off with Safety*—This advantage applies with equal, if not greater force, to catapult launching, since, with the latter, the car runs on fixed rails and launching from a car should be easier than from another aircraft in flight.

   Blind take-off, under condition of poor visibility, in fog or rain or at night, is part of the regular routine in the D.L.H. service using catapults. Such take-off should therefore be relatively simple and straightforward with larger shore catapults.

It is clear from the foregoing that the assisted launching of aircraft by means of the composite aircraft possesses, for commercial operation over a permanent route, only the one advantage—that of launching at height—and that this advantage is offset by advantages possessed by the fixed long-run land catapult.

The economic advantages to be derived therefrom justify the provision of equipment for launching aircraft on the transatlantic service and, from the foregoing, it is concluded that the most promising means of launching is the fixed long-run shore catapult.

Meteorological Service

An efficient meteorological service for the collection of weather reports and the preparation of forecasts is one of the most vital elements of the ground organization of a transatlantic route.

The service should be equipped and organized to provide the pilot at take-off with a detailed weather forecast for the flight. This forecast should be as complete as possible, not only with respect to surface conditions, but also, insofar as existing knowledge permits, with respect to upper air conditions.

It is reported that the meteorological work on the western side of the Atlantic, for the proposed air service, was undertaken by Canada in 1935 and that the organization of the work is now actively proceeding.

The forecasts of the Meteorological Service of Canada[21] are prepared twice daily, at 8.00 a.m. and p.m., on weather reports received from some 69 Canadian stations and from 159 in the United States. Reports are also received from 4 stations in Greenland and one in Bermuda, together with about 25 daily reports from Europe. An average of 12 to 16 reports are received from ships on the Atlantic, of which 5 or 6 are between Ireland and Newfoundland.

Recently 2.00 p.m. observations have been received from 34 stations in Canada, 135 in the United States and 6 in Newfoundland, for the preparation of 2.00 p.m. weather maps which are used to correct forecasts.

For adequate forecasting for the transatlantic air service, observation and reporting facilities should be increased in the region between Newfoundland and Bermuda and additional facilities provided in the Ungava peninsula, northern Ontario and the Canadian Northwest. Weather observations are now made in these regions from Dawson, Mayo, Aklavik, Fort Norman, Simpson, Smith, McMurray, Coppermine, Chesterfield Inlet, Nottingham island, Cape Hope's Advance, Resolution Island, Churchill, Moosonee, Chibougamau and Cartwright.

It is essential that the number of upper air observations be increased. At the present time, such observations by balloon are made only at Sable island, Fredericton, Clarke City, Dolbeau, Moosonee, Toronto (also by aircraft, to 10-12,000 ft.), Winnipeg, Vancouver and Victoria. Reports of aeroplane observations are received daily from a maximum of 22 upper air stations and of pilot balloon observations from 50 stations, in the United States.

Regular aviation forecasts by the Canadian service are now confined to those for the Montreal-Rimouski, Montreal-Albany, Montreal-Ottawa and the north shore of the St. Lawrence, Rimouski-Harrington Harbour services and for the Rouyn area. Pilots on the Montreal-Rimouski service report in detail the weather encountered.

With the inauguration of the trans-Canada air service in the near future, an extensive and frequent aviation forecasting service will necessarily be organized which will be exceedingly useful in connection with the transatlantic service.

Additional weather reporting facilities, particularly respecting upper air conditions, will be required at the European end of the route. A special forecasting station is being established at the Foynes base in Ireland.

There is a fully equipped meteorological station and forecasting centre at Bermuda at which pilot balloon observations are regularly made. It is being prepared for service in connection with Atlantic air routes.

Since 1934, upper air conditions over Newfoundland and the Gulf of St. Lawrence have been studied at meteorological stations and by means of aircraft. There are now operating, nine stations in Newfoundland. Pilot balloon observations are made from two of these and aeroplane observations at one station. A preliminary analysis of records extending over ten years to determine wind speed and direction was completed in 1936.

Upper air observations should be made, if feasible, by balloon, from transatlantic steamers, preliminary to the establishment of the air service and possibly during the operation of the service. However, knowledge of upper air conditions over the Atlantic will be built up principally on the reports of the crews of aircraft operating the service, when established.

---

[21]Information kindly furnished by the Director.

A comprehensive weather forecasting system is being arranged, to include the establishment of an extensive network of stations in Newfoundland, for furnishing information to a central forecasting station at Botwood, provision for the training of forecasting personnel and the study of the meteorological problems connected with the operation of the transatlantic service.

With a flight weather forecast, complete in every possible detail, based on the latest weather analysis and using modern forecasting methods, furnished immediately prior to each flight, and with aircraft having a reasonable margin of range over the minimum, rigid adherence to the great circle course will be unnecessary, and the most favourable course and flying levels can be used as was done by Costes and Bellonte on their westward flight and as is being done on the Pacific flights. Not only should the best course and levels to take advantage of favourable and avoid unfavourable winds be worked out in advance, but also all other possible flight details based thereon, such as cruising speeds, engine operation, times, etc.

Radio Service

The importance of adequate radio services in connection with the operation of a transatlantic air service is obvious. Every effort should be made to provide the most up-to-date and dependable equipment. In addition to equipment of proved efficiency and reliability, provision should be made for service trials of promising new developments.

The function of the radio service will be threefold, namely as a means of communication, as an aid to navigation and as a guide in blind landing.

Two-way communication between aircraft and the route terminals, shore stations and ships at sea is necessary to permit the pilot to secure flight information as to weather ahead and airport conditions, to report his progress and position and weather encountered and to call for help in an emergency.

For this service, there should be provided both short and medium wave equipment for two-way communication, by voice and key, to ensure absolute dependability under all conditions.

Ordinary two-way communication over water, with aircraft equipment is now practicable over distances of 3,000 miles and is possible under certain conditions up to nearly 4,000 miles.

For navigation across the Atlantic and between stations, radio at present will be relied upon primarily to check and supplement navigation by the well tried and proved methods based on celestial observations and dead reckoning, using such new and improved instruments as have been developed for aircraft use.

Radio direction-finding equipment has proved quite accurate, even over long distances, in flight over the South Atlantic and Pacific and indeed it must be largely relied upon for navigation under conditions of poor visibility. For the determining or checking of position and course, dependence will be placed principally on fixes obtained from shore D.F. stations, verified by bearings taken, using direction-finding equipment in the aircraft, on shore stations, steamers or even broadcasting stations.

Long range aviation D.F. equipment now in service is capable of determining bearings within 1° at 250 miles or less and within 3° at ranges from 1,200 to 1,600 miles, at frequencies from 6,000 to 250 kilocycles, and bearings have been obtained at a range of over 2,000 miles. The equipment is relatively free from night effect. A rotatable (and retractable) loop is of course used to permit the taking of bearings without deviating from the course and to permit "homing." Indications are both aural and visual.

While bearings determined at shore D.F. stations are more accurate and will normally be depended upon for fixes, bearings determined with the direction-finding equipment in the aircraft will be found useful and convenient and will doubtless be regularly employed as a matter of routine.

The pilots of the D.L.H. South Atlantic service rely almost wholly on their own bearings taken on the depot ships and shore stations, using medium wave, although the bearings are compared with those obtained by the depot ships.

For the direct transatlantic route to be inaugurated in 1937, large up-to-date D.F. stations are being erected at Foynes, County Limerick and at Ballygirreen, County Clare, in Ireland and at Botwood, Newfoundland. Doubtless other D.F. stations will be provided in Newfoundland and possibly some of the numerous marine D.F. stations of the Department of Transport, along the Atlantic coast and Gulf of St. Lawrence, will be equipped to serve as D.F. stations for the transatlantic service.

Guidance in blind landing is the third duty of radio in the operation of a scheduled commercial air service. The aircraft, having been navigated by means of one or all of the three available methods to within 100-200 miles of the terminal, then picks up the beam from a radio beacon and follows it in. When 10-15 miles from the beacon, the ultra short wave (about 9 m.) fan-shaped landing beam is picked up and followed, passing, at between 1 and 2 miles from the landing area and at about 2,000 ft. altitude, the vertical conical beam of the first marker beacon. Following the curved lower fringe of the landing beam, the second marker beam is passed about 300 yards from the boundary. Continuing to follow the fringe of the beam, the aircraft is brought within a few feet of and parallel to the surface. By slowly throttling and easing back on the control, the aircraft is put down. Both visual and aural indication is provided.

Insofar as is known, blind landing equipment of this kind has not been used over water. The difficulties involved appear to be mechanical since there is nothing to interfere with the electrical principles involved. The fixing of the small transmitters for the beams and markers, to prevent their disturbance by wave action, to allow for tides and so that they may be out of the way presents difficulties.

Several British, most German and many other European airports are now equipped with one or other of the several types of blind landing equipment, now perfected, and blind landings are made as a matter of routine.

Needless to say, the terminals and stations of the transatlantic route should be so equipped.

In this connection, for use, both for navigation and approach to the airport, the direct reading radio compass, using a cathode ray oscillograph tube as an indicator, is very promising. This compass, invented in Canada in 1924, by Major-General A. G. L. McNaughton and Lieut.-Col. W. Arthur Steel is now undergoing development in the laboratories of the National Research Council. It has been improved by Dr. J. T. Henderson to indicate sense as well as direction of the bearing and the sensitivity of the receiver has been increased. The compass possesses a number of points of superiority, including immunity from noise and interference effects, simplicity of operation, ease of reading and the possibility of securing simultaneous bearings on two or more stations. The compass is to undergo service trials in Canada in 1937.

AIRCRAFT

Aircraft of the heavier-than-air type differ from all other means of transport in which the weight is supported directly by the ground or through displacement, in one very

important particular, namely the variation of power with economic speed. With land transport, the power increases rapidly with speed. Similarly with ships there is a limiting economic speed depending on the size and shape of the hull beyond which there is a prohibitive increase in power. On the other hand, there is for every aeroplane a most economic speed in relation to its load and any increase or decrease in this speed adversely affects the economy (see Fig. 24).

The wing characteristics are such that high efficiency is attained only over a limited range of incidence. Operating at this favourable incidence and varying the speed by variation of wing loading or altitude of flight, the power increases only as the speed.

A comparison of air transport with other means of transport is given in Table IV. The figures are approximate only but are probably sufficiently accurate for the purpose.

Table IV Comparison of Means of Transport

(a) Passenger

	Number of passengers	Cost per passenger (dollars)	Weight per passenger (short tons)	Hp. per passenger	Speed (m.p.h.)
Modern de luxe liner...	Up to 3,000	20-25,000	40-50	80-85	30-33
Small liner...........	800	17-19,000	35	40	20 25
Railroad train, steam..	400	4-6,000	0.5-2.0	10-20	50 60
Railcar, I.C. engine....	30-50		2.0	10	50-60
Motorcar.............	5	150 up	0.3-0.5	10-20	30-60
Airship...............	50-72		2.5-5.0	70-130	75-86
Aeroplane—boat.......	30-50	6-9,000	0.25-0.6	75-125	150-180
wheeled....	8-10	5-10,000	0.3-0.8	90-180	180-200
wheeled....	5-6	2-6,000	0.3-0.6	75-150	180-200

(b) Freight

	Capacity (short tons)	Cost per short ton capacity	Weight per short ton capacity	Hp. per short ton capacity	Speed (m.p.h.)
Freighter............	Up to 12,000	Up to 60	0.5-1.5	0.25-0.6	10-18
Railroad train, steam...	1,500	200-250	0.3-0.5	0.3-0.5	30-50
Truck...............	5-10	1,000	1-3	2 up	40-50
Airship...............	15-20		6-10	180-250	75-85
Aeroplane—boat.......	2-8	Up to 70,000	2-4	500-750	150-180
wheeled....	1-2	20-25,000	1.5-2.5	200-500	180-200

Existing Aircraft

In Tables V-VI, the reported characteristics and performances of some 70 civil aircraft, aeroplanes, flying boats, seaplanes and amphibians, have been tabulated in order of gross weight and in Figs. 17 (columns 1 and 2), and 18 are given, insofar as available, their line drawings, all to the same scale and arranged also in order of gross weight. There have been included long range, large capacity, large size, high efficiency and other aircraft, selected because of their interest in this connection.

These tables and drawings were prepared at the end of 1935. Table VII and Figs. 17 (column 3) and 19, containing particulars of certain aircraft published during 1936 were prepared early in 1937 and hence the aircraft included therein are not in proper order with respect to those of the earlier figures and tables.[22]

In column 29 of the tables is given a figure for the transport efficiency. This figure is the disposable load, in short tons, multiplied by the cruising speed in miles per hour and divided by the total rated horsepower and is therefore expressed in ton miles per hour per horsepower. It is used as a simple and reasonable measure of the value of the aircraft as a means of transport.

[22]The aircraft of Table VII and Figs. 17 (column 3) and 19, have been designated with a number and letter to indicate their relation to those of the other tables and figures.

Table V

Flying Boats, Seaplanes, Amphibians (Civil)

No. 1	Aircraft: Builder, Number Name 2	Type 3	Engines: No 4	Engines: Type 5	Rated HP: H.P. 6	Rated HP: Height 7	Airscrews 8	Dimensions: Span 9	Length 10	Height 11	Lift'g Area 12	Weights: Tare & Equip't 13	Capacity: Gas 14	Capacity: Oil 15
1	Dornier DOX-1a	HWMB	12	Conqueror	600?	-	6tr 6pu4bl	157-5	131-4	29-6	4885	68800	41000	-
2	Latécoère 521 Lieut. de Voisseau Paris	HWMB	6	Hiso 12Ybrs	800	13220	4tr 2pu3b	160-0	103-0	29-6	3554	43454	38400	
3	Supermarine-projected	MWMB	6	Buzzard	825	0	3tr 3pu	174-0	107-0	32-0	4000	50600		
4	Latécoère 300 Croix du Sud	HWMB	4	Hiso	640?		2tr 2pu 2b	145-0	85-0	21-4	2800	26670		
5	Glenn Martin 130	HWMB	4	Twin Wasp. R1830S1AG	800	7000	4tr 3b C.P	130-0	90-10	24-7	2315	23100	24000	1800
6	Latécoère 30-1	HWMB	4	Hiso 12Nbr	650	0	2tr 2pu.	144-11	84-7	20-11	3292	24900		
7	Bleriot 5190 Santos Dumont	HWMB	4	Hiso 12Nbr	650	0	3tr.1pu 3b.CP	141-0	85-3	-	2389	24640		
8	Liore et Olivier H-27	MB	4	Hiso 12Nbr	650	0	2tr 2pu.3b	120-5	68-10	21-4	1937	20526	14800	
9	Sikorsky S-42 Brazilian Clipper	HWMB	4	Hornet S5D-1G	700?	3500	4tr. 3b CP	114-2	67-8	17-4	1330	21945	7440	555
10	Brequet Saigon	S.B	3	Hiso 12Ybr	800	-	3tr	115-0	66-8	-	1800	21025		
11	Short Scipio	BB	4	Jupiter XFBM	555	4000	4tr 2b	113-0	78-5	28-0	2640	20460	5180	480
12	Savoia S-66	HWMB	3	Fiat A24R	700	-	3pu.4b	108-3	54-6	16-0	1363	16940		
13	Short Calcutta	BB	3	Jupiter X1F	495	0	3tr.	93-0	64-9	22-3	1825	17800	3520	
14	Dornier Wal 1933-34	HWMB	2	BMW-VI	500		1tr 1pu.3b	89-3	59-9	19-1	1220	12340	7460	151
15	Latécoère 38-0	HWMB	2	Hiso 12Nbr	650	0	1tr. 1pu4b	103-0	55-0	19-9	1400	11720		
16	Latécoère 50-0	HWMB	3	Hiso 12Jb	400	-	2tr. 1pu.	103-0	58-2	16-3	1378	9780		
17	Sikorsky S-43	Amph.	2	Twin Wasp S1EG	750	7000	2tr 3b.CP	86-0	51-2	17-8	781	10200	5550	480
18	Junker Ju 52-3m Ju 52	LWMF	3 1	Jumo 5 Jumo 4	420 600	- -	3tr. 2b 1tr.4b	96-9	62-4 60-8	17-9 21-4	1189	13290 10150		
19	Latécoère 50-1	HWMB	3	Hiso 12Jb	400	-	2tr. 1pu	75-5	57-0	13-8	861	8200		

No. 1	Normal Load: Gas 16	Normal Load: Oil 17	Crew: No 18	Crew: Wt. 19	Pass No 20	Pay Load 21	Dispos. Load 22	Gross Weight 23	Figures of Merit: Wt. Ratio 24	Loading: Wing 25	Loading: Power 26	Wing Power 27	Speed Ratio 28	Trans Effy 29
1	25200	3762			75		54400	123200	1.79	25.3	17.1	1.47		0.397
2	9400		4	880		15800	38046	81500	1.87	22 9	17.0	1 35		0.495
3							23400	74000	1.46	18.5	150	1.24		0.291
4	21740		3	705	0	2200	25930	52600	1 97	18 8	20.5	0.91		0.563
5					50	Var	27900	51000	2.21	22 0	15.9	1.38	2.57	0.675
6	22850		4	705	0	2210	25700	50600	2.03	15.4	19.5	0.79		0 544
7			8			1320	24860	49500	2.01	20.7	19.0	1.09		0.526
8			4				19514	40040	1.95	20.7	15.4	1.34		0.488
9	7995		5		32	8060	16055	38000	1.73	28.6	13 6	2.10	2.89	0.487
10			3	705	19	7200	12025	33050	1.57	18.4	13.8	1.33		0.310
11	3420		3	660	15	7460	11540	32000	1.56	12.1	14.4	0.84	2.28	0.273
12	2530		3	660	18	3960	7150	24090	1.42	17.7	11.5	1 54	2 48	0.248
13			2	400	15	4300	4700	22500	1 27	12.3	15.2	0.81	2 02	0.147
14			4				9700	22040	1.78	18.1	22.0	0.82		0.630
15	8255		4	775	0	1100	10130	21850	1 87	15.6	16.8	0.93	1.89	0.428
16	10100			705		1100	11870	21650	2.21	15.7	18.0	0.87		0.550
17	2400	180	3	510	0	1000	7650	17850	1.75	22.9	11 9	1 92	3.08	0.461
18			2		14-17		6980 6590	20270 16740	1.52 1.65	17.1 14.1	16.1 279	1.06 0.50		0.398 0.571
19	2803		2	352	10	2315	5480	13680	1.67	15.9	11.4	1.40		0.234

No. 1	Performance: Max. Speed S.L. 30	Max. Speed Ht 31	Max. Speed Speed 32	Cruising Speed %HP 33	Cruising Speed Ht 34	Cruising Speed Speed 35	Ceiling Abs 36	Ceiling Serv. 37	In. rate Climb 38	Landg Speed 39	Range-no wind Rated 40	Range-no wind Flown 41	Notes 42	References. 43	No. 44
1	130					105	6588		230		2000	1450	Gross weight DVL rating Range 2000m with no pay load Climb and ceiling for 105600 lbs gross	Jour RAeS Sept 33 L'Aero Oct 30 Aero Dig. Nov 31	1
2	156					125	16400				2812		Estimated performance. Range with normal fuel 620m N.Atlantic via Azores 24 pass. S.Atlantic-30pass	Flight 24.1.35 Rev Aero Apr 35 Aero 23.1.35 Air Engng May 35	2
3	145					123	11000				690		Projected 1931 for Trans Mediterranean Service Max range 1300 m.	Rev Aero Feb. 31. Aero 20.2.35	3
4	130					111	15000				2980	2685	Mail carrier, normal gross 51300. Record. Dec 34. Berre-Ste Louis de Senegal, 2600m-S Atlantic 2010m-18h17. Record June 35 Cherbourg-Ziguinchor, Senegal 2685m-28h30	L'Aero Dec 34 Air Engng May 35 Aerophile Jan 34 L'Aero Dec 31	4
5	180	8000	180	60	6500	155		18000	980	70	4000	2100	Range as mail carrier 4000m, with 52pass 1200m., with 14 pass. and 2000 lbs mail 3000m Alameda, Calif.-Honolulu 2100m-17h9 Aug 35. Tare ocean pass transp 28216lb Cost $325000	Flight 24.1.35, 15.8.35 Aviat Jan 35 Aero 23.1.35. Aero Dig. Jan Apr 35	5
6	130					110	15100				2980		Postal aircraft - S Atlantic	Jane	6
7	136					110					2000	1890	Dakar-Natal Nov.34. 1890m. 16h25. Dec 34. 15h45. Natal-Dakar. Dec. 34. 19h 7. Range against 31m.ph wind. For S Atlantic 4-1000HP motors if passenger (60) carrier	Aero Dec 12 19.34 Air Engng Feb 34 Aerophile Jan. 35	7
8		5000	152			129	13000		400?		2484		Long range postal-S.Atlantic. Recent test, 16900 lbs fuel, payload 1320 lbs, gross 41900 take off 39 sec.	Aero Jan 23.35 L'Aero Dec. 34 Air Engng May 34	8
9	180	5000	188	70	12000	170	16000		1000	65	3000	2500	Range 1200 with payload shown. 3000 with 800 payload. Record 1242m.-payload 4409 lbs. 157m.p.h. Miami-Virgin Isds return Mar.35 2500m fuel for 500m left. Cost $275000	Aviation Apr Aug. 34 Jan 35 Jour RAeS Apr. 35 Aero Dig Aug 34	9
10	146	3280	149			124	16400				680		Civil version of Bizerte Performance for 30400 lbs gross Tanks for 1240m. For Marseilles-Algiers service	L'Aero Dec 34.	10
11		5000	137		5000	105	19500	17500	840	60	450		Kent class, similar to Calcutta. Launched Feb 31. For Mediterranean service. Actual performance at gross shown	Jane 34. Flight 17 10.30	11
12	164					146	18530		850	69				Jane 34 Rev Aero May 32.	12
13	123					93	14000	12000	615	61	651			Jane 33	13
14	143					130					2230		For Trans Atlantic service Mail, freight or passengers	Jane 34 Z F.M No15 33.	14
15	130					110	14780			69	2980		Postal Performance S.T.Ae test 1931 with full load	Jane 34 Air Engng Jan. 31	15
16	130					111	15090				2980		Postal	Jane 34	16
17	186	7000	200	75	8000	181		20000	1250	65	2000		Range as mail carrier at 12000ft and 165mph Range as a boat 2500m. Range with 15 pass and 750 lbs mail-750m., with 25 pass and no mail-390m.	Flight Jan 24, June 20.35 Aviation Dec 34 Aero Dig Jul 35	17
18	161 121					144 104	19020 14100	17050 10820	900 450		- 1160		Freight or passenger Single motor range on wheels 1240m.	Jane 34 ZFM Nall. 33.	18
19	149	3280	144			127	18432						Commercial boat. Official test performance.	L'Aero Aug 32 Jane 32	19

Table VI
Aeroplanes
(Civil)

No	Aircraft		Engines				Airscrews	Dimensions				Weights											Figures of Merit						Performance												Notes	References	No.
	Builder, Number Name	Type	No	Type	Rated HP			Span	Length	Height	Lift'g Area	Tare & Equip't	Capacity		Normal Load		Crew		Pass.	Pay Load	Dispos. Load	Gross Weight	Wt Ratio	Loading		Wing Power	Speed Ratio	Trans Effy	Max Speed			Cruising Speed			Ceiling		In rate Climb	Land'g Speed	Range-No wind				
					HP	Height							Gas	Oil	Gas	Oil	No	Wt	No					Wing	Power				SL	Ht	Speed	⅔HP	Ht	Speed	Abs	Service			Rated	Flown			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
1	A.N.T. 15 Maxim Gorky	HWM	8	M.34	750 850	-	7tr.1pu2b	210-0	107 0	34-6	-						23 -		40 6070	14000		92600?							149?					137?					1240?		Propaganda aeroplane.	Rev. Aero. Nov. 34, Flight 4.8.34 Aero. Dig. Sept. 35.	1
2	Junker G-38 von Hindenberg	HWM	4	Jumo 4	750	-	2tr 4b. 2tr 2b	144-4	75-6	22-6	3285	32800					7		34	6600	20100	52900	1.61	16.1	17.6	0.91		0.434	139					129	20990		650		2180		Range with 6600 lbs freight. Range with L 88 engines 746 m. Abs. ceiling 3 engines 6560	Air. Engng Feb. 30. L'Aero Mar. 30	2
3	A.N.T. 14.	HWM	5	Jupiter 9AKK	480	-	5tr 2b	132-5	86-11	17-9	2585	23450							36		14700	38150	1.63	14.7	15.9	0.93	2.92	0.323	136					116		13120		47				Jane 34.	3
4	Couzinet 70 Arc-en-Ciel	LWM	3	Hiso 12Nbr	650	-	3tr.2b.	98-6	53-0	13-1½	970	16100	18600		18690			882		1323	20900	37000	2.30	38.2	19.0	2.01		0.790	174					147					4230	2633	Istres-Rio return Jan 33 crew 5. Istres-Pt. Etienne Jan 12-13. 2633 m 16h 30. St Louis-Natal Jan 16-17. 1970 m-14h 27	Air. Engng Feb 34. L'Aero Feb. 33 Aero 25.1.33	4
5	Fokker F XXXVI	HWM	4	Cyclone SGR 1800 F2	710	4100	4tr.3b CP	108-2	78-8	19-8	1851	23760® 24531	5380	435	3967		4 5	705	16 32	4580 7163	11440 11835	35200 36366	1.48	19.6	12.8	1.53		0.351 0.362		4100	186	75	9840	174	16400	14450	750		960		Range at cruising speed with full tanks	Fokker Bull 34.	5
6	Short Scylla	B	4	Jupiter XFBM	555	4000	4tr 4b.	113-0	86-3	29-6	2615	22650	4500				4		39		9350	32000	1.41	12.2	14.4	0.85		0.221		5000	137		5000	105					600		Range with full tanks, payload then 5250 lbs	Flight 5.4.34	6
7	Handley Page HP42 Hannibal Heracles	B	4	Jupiter XI Jupiter XFBM	550	4000	4tr 4b	130-0	89-9	27 0	2990	-	3600						18 38	7000 9000	- -	28000 30000	- -	9.4 10.0	12.6 13.5	0.74	2.40 2.47	- -	120 127					95-105			845 670	50 51.5	500			Jane 34.	7
8	Savoia S 74	HWM	4	Piaggio Stella IXRC	700	-	4tr 3b CP	98-5	63-11	18-0	1291	17160	5210		3300	330	4	990	24	6390	11880	29040	1.69	22.5	10.4	2.16		0.395		3280	199		9840	186		19680	950		714		Range for fuel weight shown. Same wing as S 55 boats. Max permis gross. 30870 lb	L'Aero June 35, Aero 6.2.35, Aero Dig Mar 35, Flight 3.1.35, 14.2.35	8
9	Fokker F XXII	HWM	4	Wasp S3H1G	550	5000	4tr 2b CP	98-4	72 2	16-1	1399	18300 20056	4270	427	3152		4	661	22	3585 4783	9750 8596	28050 28652	1.43	20.5	12.9	1.59	2.77	0.363 0.320		5000	177	75	10500	165	17700	16100	700	64	932		Range with full tanks. 3 for K L M, 1 for Sweden	Fokker Bull. Aero 9.1.35 Flight 21.2.35 Rev Aero Dec 33	9
10	Savoia S 79	LWM	3	Piaggio Stella IXRC	610	-	3tr 3b CP	66-3	53 2	13-6	646	11000	10200 6150	720	2930	285	4	880	8	1200 2507	13300	24300	2.21	37.6	13.3	2.84	3.88	0.790	220	13120	248	70	13120	217		23290	540	64	930		For MacRobertson Race - not ready; tested Nov 34. speed 249 mph. Performance with 6600 disposable. To be used Rome-Rio	L'Aero June 35. Aero 12.12.34 6.2.35	10
11	Armstrong Whitworth AW-15 Atalanta	HWM	4	Serval	340	SL	4tr 2b	90-0	71-6	14 0	1285	13900	2330	270	1600			550		5000	7100	21000	1.51	16.3	15.4	1.06		0.322		3000	156			125	7000		700		660		For tropical service. Normal range 400 m. Abs ceiling on 3 engines	Air Engng Aug 32	11
12	Fokker F XX	HWM	3	Cyclone R 1820 F3	712	700	3tr 2b	90-2	54-9	15-7	1033	13450	4120	148	4102			530		2645	7278	20728	1.54	20.0	9.7	2.06		0.320		6890	202	75	12460	188	23288	21650	1000		1056		Range for full tanks. Normal fuel for 963 m	Aero Dig Jan 34. Jane 34. Fokker Bull 33	12
13	Dewoitine D 332	LWM	3	Hiso 9Vr	575	-	3tr 2b	95-0	62-1	17-10	1032	12162	5070	2300	4850			596	8 16	3060	8506	20668	1.70	21.0	12.0	1.67		0.430	187	6562	177	80	6562	175	21325		1000		1305	1305	Performance for gross of 20200 lbs. Endurance test with full tanks, gross 21395 lbs range 1305 m. Descendent of D-33	Air Engng Feb 34. Jane 33	13
14	Bernard 81GR	MWM R	1	Hiso 12Ybrs	650	-	tr 3b	87-0	50-11	14 9	811	7270	11100								13110	20380	2.80	25.1	31.4	0.80		0.989						98					6210			Aeroph Oct. 32 Jane 33	14
15	Dewoitine D-33 Trait d'Union	LWM R	1	Hiso	650	-	tr 2b	92-0	47-2	15-10	-	6830	12650	760							13470	20300	2.97	-	31.2	-		-												2900	Record long range - Doret and LeBrix - closed circuit, Mar 31, 2900 m - 32h 18.	L'Aero May 31	15
16	Bernard 80GR	MWM R	1	Hiso 12Nb	650	-	tr 2b	80-4	48-6	13-1	753	6820	11100	700							12155	18975	2.78	25.2	29.2	0.86		1.075	155					115	8200				8070	5560	Theoretical range. Closed circuit record France Mar 31. 5560 m - 59h 14	L'Aero June 31	16
17	Bleriot 110 Joseph le Brix	HWM R	1	Hiso 12	650	-	tr 2b	86-11	47-9	16-0	871	5500	11100	600							13420	18920	3.44	21.7	29.1	0.75		1.030	137					100	6560		275		7825	5654	Record - duration 1930 - 67h 53. Record - closed circuit - 32 - 6703 m. New York - Rayak - 33 - 5654 m. Paris - N.Y. - 34 - 3280 m - 38h 30. Istres - Cap Verde Isd - 35 - 3790 m. Range estimated on this 7456	L'Aero Dec 30. Flight 28.3.35	17
18	Dewoitine D 333 Antares	LWM	3	Hiso 9V Cyclone	575	-	tr 2b	95-2½	56-7	17 7	861	9117	5120	504	4840			594		3925	9359	18476	2.02	21.5	10.7	2.00		0.433	188					160					1260		Range with normal load. Development of the Emeraude	Flight 3.1.35. Jane 34	18
19	Douglas DC-2	LWM	2	Cyclone SGR-1820-F3	710	7000	2tr 3b CP	85-0	62-0	16-4	940	12000 12200	3060	285	3060	285	2	353	8	2317	6000	18200	1.49	19.4	12.8	1.51	3.68	0.414	213	7000	210	75	12500	196	24800	23200	1090	58	1200		Closed circuit records May 35. 1240 m 4410 lbs pay load 191 mph - All up weight 24845 lb. 3110 m no pay load 169 mph. 3110 m 2200 lbs pay load 169 mph	Fokker Bull 34 35. Aero Dig Apr 35	19
20	Curtis Condor	B	2	Cyclone SGR-1820-F3	710	7000	2tr 3b CP	82-0	48-7	16 4	1208	11465	2100	225	2100	225		510		3200	6035	17500	1.53	14.5	12.3	1.18	3.65	0.354	190	8000	190		8000	167	25000	23000	1200	52	716		Standard passenger transport day model	L'Aero Nov 33. Jane 34	20
21	Fairey Long Range	HWM R	1	Lion XI A	570	-	tr 2b	82-0	48-6	-	830	-	8903	641			2			0	-	17500	-	21.1	30.7	0.69		-						93						5341	Record Feb 33 Cranwell - Walvis Bay - 5341 m 57h 25. Capacity 1157 gals gas (@ 7.7 lbs/gal.) and 65 gals oil (@ 9.7 lbs/gal)	Air Engng Mar 33 Flight 16.2.33	21
22	Fokker F XVIII Snipe	HWM	3	Wasp T1D1	525	SL	3tr 2b CP	80-10	60-8	15-7	904	10805	3180	110	2492		2	352		3660	6505	17310	1.60	19.2	11.0	1.74		0.324		5248	168		11152	157	20340	18700	950		2860	2245	Range with 6 extra tanks 1078 gal - gross 22046 lb. Flight Holland - Dutch West Indies Dec 34 Porto Praia - Paramibo 2245 m 17h 30. Range 620 m with fuel and pay load shown	Fokker Bull Aerotec Dec 32 Flight 8.11.34	22
23	Boeng 247 D	LWM	2	Wasp S1H1G	550	8000	2tr 3b CP	74-0	51-4	12-2	836	8940	1640	150			2		10	2582	4710	13650	1.53	16.3	12.4	1.32	3.31	0.404	202	8000	200		12000	189	23300	21400	1000	61	835		Range at 62.5% HP and 8000 ft. Range 745 m at 75% HP and 8000 ft	Aero Dig Apr 35 Aeroph Nov 34	23
24	Brequet 393T	S	3	Gnome 7Kds	350	9971	3tr 2b	68 0	59-10	12-2	723	7660			3125			1320		880	5540	13200	1.72	18.3	12.6	1.45		0.342	153					130		19600			1000		As long range mail carrier	L'Aero Dec 34	24
25	Ponder Postjager	LWM	3	Whirlwind R975 E2	420	-	3tr 2b	54.5	41-0	9-6	484	6655	3280	260			3		0	1100	5445	12100	1.82	25.0	9.5	2.60	3.73	0.403	224					186				60			High speed mail carrier	Jane 34	25
26	Fiat APR-2	LWM	2	Fiat A59R	700	6562	2tr 2b CP	64-0	47-0	11-8	636	8820			2870		3		12		3150	11970	1.36	18.8	8.5	2.20	3.78	0.231		6560	238			205				63	1242		With extra tanks	L'Aero Feb 35	26
27	Lockheed Electra 10C	LWM	2	Wasp SC1	450	6000	2tr 2b CP	55-0	38-7	10-1	458	6710	1560	127			2		10	2200	3590	10300	1.54	22.5	11.5	1.96	3.16	0.383		6000	205		12000	194		22750	1050	65	875		Price $50000	Aero Dig Apr 35	27
28	Couzinet 33	LWM R	3	Gipsy III	120	-	3tr 2b	53-0	35-11	9-4	369	3632	3670								4323	7955	2.19	21.6	22.1	0.98		0.709						118			670		3350			L'Aero Dec 32. Jane 33	28
29	Northrop Delta 1D	LWM	1	Cyclone SR1820F3 Hornet SD	710 700	7000 6000	tr 2b CP	47-10	33-1	11-4	363	4200 4540	1968 1915	165 144			1-2		4-6	1295	2810	7350	1.62	20.3	10.4	1.96	3.72	0.416		4000	216		13000	192		22000	1200	60	1700		Freight version Gamma. Special model for Hawkes Vancouver Quebec - two stops Aug. 33. 17h 10, also Los Angeles - New York 2520 m 13h 37. Price $37500	Aero Dig Apr 35 Aviat Apr 35	29
30	Coudron C 440	LWM	2	Renault	210	-	2tr 2b CP	57-9	43-7	6-5	430	3947					2		6		2668	6615	1.67	15.4	15.8	0.98	3.05	0.515	180					162	16400			59	1242		Estimated performance. Engines non supercharged versions of Renault Special	Flight 14.6.34	30
31	Airspeed Viceroy	LWM R	2	Cheetah	315	7000	2tr 2b	52-4	34-6	9-6	299	3900	1950	-			2				2400	6300	1.61	21.1	9.8	2.10	3.14	0.348		7000	210		7000	190			1000	67	1400		As for MacRobertson Race - commercial has smaller tank and carries 6-8 passengers - disposable load about 2500 lbs	Jane 34	31
32	Bellanca Senior Pacemaker	HWM	1	Whirlwind R 975 E2	420	-	tr. 2b	50-6	27-11	8-6	311	3000	1200	90	1140		1	170	5	850	2350	5350	1.78	17.2	12.7	1.35	2.80	0.493	165			75	12000	155		18000	900	59	1360		Price $19500	Aero Dig Apr 35	32
33	De Havilland DH 88 Comet	LWM R	2	Gipsy Six Special	224 235	SL	2tr 2b CP	44-0	29-0	9-0	189 212	2840 2983	1870 1962	126 155			2 2	400 400			2480 2567	5320® 5550	1.87 1.86	28.1 26.1	11.9 11.8	2.37 2.21	3.01	0.625 0.612	235					225	19000		900 1200	78	2900	2530	England - Baghdad 2530 m 12h 40. Belgian Reine Astrid range 2000 m with 200 lb mail. France tankage for 2250 m with 220 lb mail	Flight 27.12.34 Jou. RAeS Mar 35.	33

The particulars of the aircraft listed indicate the recent and present position of commercial aircraft with particular reference to range, capacity and size and may serve as a guide in developing aircraft suitable for the Atlantic service.

Factors Governing Air Transport Efficiency

The factors controlling the efficiency of air transport are those governing the attainment of maximum range. Improvements and economies which extend range also improve economy of transport over shorter distances. Thus the steady increase in the world distance record is perhaps a surer measure of the progress of air transport than is the raising of the speed record.

A study of the factors affecting range will therefore be useful in considering aircraft for use for the transatlantic service. From such a study, it will be evident that the principal factors affecting economy of operation are the aerodynamic efficiency of the aircraft and airscrew, the structural efficiency of the aircraft, the power plant efficiency and the efficiency of navigation, including choice of height, speed and course with respect to weather conditions.

These and other considerations involved in determining the characteristics of the aircraft to be used for the service are discussed briefly in the following paragraphs.

Type of Aircraft

In considering the question of the aircraft for the service, the first decision to be made is that of the type of aircraft—aeroplane, flying boat, seaplane or amphibian. On this point, there are two schools of thought, one favouring aeroplanes, the other flying boats.

From the standpoint of efficiency, the modern flying boat, particularly in the larger sizes, is as efficient and may be more efficient than the corresponding land machine, as the figures of Tables V-VII and the plots of Figs. 20 and 25 indicate. Even with undercarriage retracted, the large commercial aeroplane is not more efficient than a well designed boat and it is probable that the efficiency of the latter will be improved still further in the future by fairing the steps in flight, retracting wing tip floats,[23] or improving the stub wings.

From the standpoint of structural efficiency, the modern boat weighing, with load, 30,000 lb. or

[23]This is already being done. See number 11A, Fig. 17.

TABLE VII

FLYING BOATS, SEAPLANES, AMPHIBIANS

(Civil)

No.	Aircraft		Engines				Airscrews	Dimensions				Weights											Figures of Merit						Performance												Notes	References	No.
	Builder, Number Name	Type	No	Type	Rated HP HP	Rated HP Height		Span	Length	Height	Lifting Area	Tare & Equip't	Capacity Gas	Capacity Oil	Normal Load Gas	Normal Load Oil	Crew No	Crew Wt	Pass No	Pay Load	Dispos Load	Gross Weight	Wt Ratio	Loading Wing	Loading Power	Wing Power	Speed Ratio	Trans Effy	Max. Speed S.L.	Max. Speed Ht	Speed	Cruising Speed %HP	Cruising Speed Ht	Speed	Ceiling Abs.	Ceiling Service	In. rate Climb	Land'g Speed	Range-Nowind Rated	Range-Nowind Flown			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
7A	Short Empire Caledonia	HWMB	4	Pegasus Xc	740	3500	4tr.3bl.CP	114·0	88·0	31-10	1500	27340 25000	4560 16700	400			5 3	800	16-24	7400 1000	13160 20000	40500 45000	1.48 1.64	27.0 30.0	13.7 15.2	1.97	2.26	0.332 0.501	200	5500	200	60		165	20000		950	73	760 3300	2500	Range still air 1000 lbs mail, crew 3, at 160 m.p.h. 3300 miles. Flew 1937 Southampton-Alexandria, 2500 miles - 13½ hrs, crew 5, ballast 800 lbs.	Flight 21.1.37, S.B.A.C.	7A
8B	Lioré et Olivier H·47	HWMB	4	Hiso 12Ybrs	880	8200	2tr.2pu.3b	104·0	69·6	23·6	1450	22200	14300				5		4	2900	17300	39500	1.78	27.3	11.2	2.43	-	0.443		8200	223	65	6560	180	22960				2484		Long range transatlantic. Gross 39683 lbs. take-off 20 secs.	Flight 14.1.37, L'Aero Nov 36 Jane 1936	8B
8A	Sikorsky S·42A	HWMB	4	Hornet S1EG	750	7000	4tr.3bl.CP	118·2	68·0	17·4	1340	23105	7995				5		32	8060	16895	40000	1.93	29.9	13.3	2.24	2.62	0.479		7000	190	75 70	S.L. 12000	160 170	20000		800	65	1200		Take-off - 30 secs.	Jane 1936	8A
9A	Loire 102 Bretagne	HWMB	4	Hiso-12Xgrs	720		2tr.2pu.3b	111·6	75·6	22·9	1480	20560	14190				4	800		2205	17240	37800	1.84	25.6	13.1	1.95		0.479	198	9840	192	55	13200	155	19700				2640		For S. Atlantic. Range with 4 pass. 1430 lbs mail.	L'Aero July 36. Rev. Aero Aug 36 L'Aerophile July 36.	9A
10A	Lioré et Olivier H·246	HWMB	4	Hiso 12Xirs	720		4tr.3bl.	104·0	69·6	23·3	1410	21600	4740						24	6650	11400	33000	1.56	23.4	11.5	2.04		0.310		6560	208			157	25600				930		Transatlantic	L'Aerophile Nov. 36	10A
11A	Douglas DF	HWMB	2	Cyclone SGR-1820 G2	1000		2tr.3bl.CP	95·0	69·11	20·2		16850	9720				4		32 12	2000	11650	28500	1.69		14.3		2.85	0.487		6500	185	75	9000	167	16000			65	2700 3280		Long range trans oceanic. Range, no pay load, 75% power - 2700 m 62½% power - 2880 m. Max. range - 3280 m.	Aviation Jan. 37 Aero 9.12.36	11A
16A	Dornier Do·18 Zephir	HWMB	2	Junker Jumo 205 CV	500 560		1tr.1pu.3bl	77·9	63·3	17-10	1054	13145	6061				4	704		330	8426	20240	1.54	19.2	18.4	1.04	2.77	0.420	155					131		14432		56	2670	2390	Ocean mail carrier. Speed 130 mph - cons. 2.29 lbs/m., at 112 mph. - cons. 2.05 lbs/m. Flew Azores-New York - 2390 m - 22 hrs - 9.9.36	Aviation Oct. Nov. 36. Aero Dig. Oct. 36. Rev Aero Feb. 36.	16A
16B	Mayo Upper Mercury	HWMF	4	Napier Rapier V	315	10000	4tr 2bl	73·0	51·0	20·3	611	9760										20000	2.05	32.7	15.9	2.06		0.650						160					3380			Jane 36. SBAC.	16B
	Mayo Lower Maia	HWMB	4	Pegasus X	810 850	4000	4tr.3bl.CP	114·0	84·11	32·7	1750								18																							Jane 36. SBAC.	

AEROPLANES

No.	Builder, Number Name	Type	No	Type	HP	Height	Airscrews	Span	Length	Height	Lifting Area	Tare & Equip't	Capacity Gas	Capacity Oil	Normal Load Gas	Normal Load Oil	Crew No	Crew Wt	Pass No	Pay Load	Dispos Load	Gross Weight	Wt Ratio	Loading Wing	Loading Power	Wing Power	Speed Ratio	Trans Effy	Max. Speed S.L.	Max. Speed Ht	Speed	Cruising Speed %HP	Cruising Speed Ht	Speed	Ceiling Abs.	Ceiling Service	In. rate Climb	Land'g Speed	Range Rated	Range Flown	Notes	References	No.
6A	Bloch 160	LWM	4	Hiso 12Xbrs				90·0	87·0		1180	19800	4900				4	700	20 8	1100	11050	30850	1.56	25.9		2.32	3.48		248			57		186	23000			65	1550		Specially constructed for Air Afrique	L'Aero. Nov. 36. Jane 36.	6A
10A	Bloch 300 Pacifique	LWM	3	Gnome Mistral Major or K14	900	4900	3tr.3bl.	91-10	82·0	16·5	1150	15750	3300				4		30	7006	10900	26650	1.69	23.6	9.9	2.39	4.52	0.420		6560	208	55	4920	170				46	746		Est. performance. Range with max. fuel and pay load 5940 lbs.	Flight. 7.11.35 Jane 1936. Jane 36.	10A
10B	Dewoitine D·338	LWM	3	Hiso 9Vd	575		3tr	96·6	72·6		1065	12680									11570	24250	1.92	22.7	14.1	1.62		0.540	187					161	17200		482					L'Aerophile Sept. 36	10B
10C	Douglas DC·3 DST	LWM	2	Wright SGR 1820 P&W. SB6 1830	850	5800 8000	2tr. CP	95·0	64·5	15·0	987	15140	4960	500					21 14		8860	24000	1.58	24.3	14.1	1.72		0.470		7000	213		10000	180	23900		950				DST Sleeper. Performance with G2 Cyclones. Guaranteed within 2% on speed, 5% on rest. Ceiling one motor 7500	Aero 26.8.36 Flight. 27.8.36 L'Aero Oct 36	10C
15A	Bloch 220	LWM	2	Gnome K14	900			74·9	46·8	14·9	775	14552	2510				3		16	2730	5248	19800	1.36	25.5	11.0	2.32		0.237	198			62		162					620		Test performance - fuel and oil for 620 m.	L'Aero. Nov. 36	15A
15B	Caproni 123	LWM	2	Gnome K14	900		2tr.3bl.	91·5	59·8	19·8	986	11686	3820				2		20		7718	19404	1.66	19.7	11.8	1.83	3.08	0.361	193	6790	211	70	6790	168		24700	800	68	932			Aviation Oct. 35 Jane 36	15B
22A	Junker Ju 86 Buckeberg	LWM	2	Jumo 205, Kestrel XVI, Hornet	750	700	2tr. CP	74·0	57·6	15·9	882	10550	1050	195					10		5900	16450	1.56	18.3	11.0	1.70	3.76	0.413		700	226		12000	210	23200			60	665	3610	Range at 210 mph. 12000 ft. with 247 gals. gas. Flew Dessau-Bathurst, non-stop 3610 m. in 20 hrs 22.8.36.	Aero 26.8.36 Flight 27.8.36 Aerotec. Oct 36	22A
22B	Lockheed 14	LWM	2	Cyclone GR 1820G3	600	15000	2tr.3bl.CP.	65·6	44·4	11·6	551						3		11			15000		27.2	8.9				238	8700	265	66 83	15000	204 228	28000		1700	65	600 1000			Aviation Mar. 37	22B
28A	Caudron C 640 Typhon	LWM	2	Renault	220		2tr 2bl.	48·6	35·11	9·10	301	4400	2706				2	396		440	3534	7920	1.90	26.3	17.6	1.46		0.818	229			75		205	23000			67	3167		Mail carrier. Range at 199 m.p.h. no wind	L'Aero Nov. 36. Jane 36. Rev Aero Feb. 36.	28A

over, is seen from the tabulated figures for the ratio of gross to tare weight and the plot of Fig. 22 to be generally superior to the wheeled aircraft. There is some indication from the figure that, as the size becomes greater, the structural weight of boats becomes proportionately less.

As the size is increased, the displacement and normal loading of the hull increases as the cube of the linear dimensions. At the same time, the larger the boat, the better the take-off, since the hump speed occurs later when the wings are carrying a larger part of the load and, due to its lower centre of gravity, the stability of the larger boat on the water is better.

Thus the large flying boat is advantageous structurally, hydrodynamically and aerodynamically.

The service being over water, it is considered by some that the flying boat should be used because of its ability to alight and remain afloat in an emergency. This reason in itself is not adequate. A wheeled aircraft, properly designed and with retracted undercarriage, could safely alight on the sea and, if provided with watertight compartments and wings, could remain afloat in fair weather probably as long as a flying boat.[24] It is contended that aircraft forced down at sea have remained afloat and crew, load and machine have been recovered on several occasions in the South Atlantic and, on at least one occasion, a land machine remained afloat some days in the North Atlantic. But in these cases, the weather was fair, with no sea. No existing aircraft, if forced down, could long survive North Atlantic seas in rough weather. The advantage of the boat in this respect is that, if forced down by a minor defect, in fair weather, it can take off again after repairs have been

[24]Service aircraft, operating from carriers, are now built with watertight compartments.

EXPLANATORY NOTES—TABLES V-VII

Col. 3—Type: HWM, High wing monoplane. B, Flying boat.
LWM, Low wing monoplane. F, Float seaplane.
MWM, Mid wing monoplane. Amph., Amphibian.
B, Biplane.
S, Sesquiplane. R, For attack on record.
Col. 8—Airscrews: tr., tractor; pu, pusher; b., blades.
C.P., Controllable or variable pitch.
Cols. 9-12—Dimensions in feet.
Cols. 13-23—Weights in pounds.
Col. 13—Weight empty plus fixed equipment
Col. 24—Weight Ratio: Gross weight divided by tare plus equipment.
Col. 25—Wing Loading: Gross weight divided by lifting area.
Col. 26—Power Loading: Gross weight divided by total rated power.
Col. 27—Wing Power: Total rated power divided by lifting area, i.e., wing loading divided by power loading.
Col. 28—Speed Ratio: Maximum speed divided by landing speed.
Col. 29—Transport Efficiency

$$= \frac{\text{Disposable load (short tons)} \times \text{cruising speed}}{\text{Total rated power}}$$

= Ton miles per hour per hp.
Col. 30—S.L.: Sea level.
Cols. 30, 32, 35, 39: Speeds: miles per hour.
Col. 38—Rate of Climb: feet per minute.
Cols. 40, 41—Range: miles.
Col. 43—Abbreviations:

Air Engng.,	Aircraft Engineering.
Aero.,	Aeroplane.
Aero Dig.,	Aero Digest.
Aeroph.,	Aerophile.
Jane,	All the Worlds Aircraft.
ZFM,	Zeit für Flug. und Motor.
Aviat.,	Aviation.
L'Aero.,	L'Aeronautique.
Rev. Aero.,	Revista Aeronautica.
Jour. R.Aes.,	Journal Royal Aeronautical Society.
Aerotec.,	L'Aerotecnica.

Fuel and Oil Weights.
Gasoline, 7.2 lb. per Imp. gal., 6.0 lb. per U.S. gal., 1.56 lb. per litre.
Oil, 9.0 lb. per Imp. gal., 7.5 lb. per U.S. gal., 2.00 lb. per litre.

Nctes
①Lifting area includes stub wings.
②Cruising speed assumed 85 per cent of maximum speed.
③Stalling speed.
④Entry data for MacRobertson Race—Flight 23-9-34.

made, or possibly taxi toward a rescue ship. The psychological effect of this factor on the crew should not be overlooked.

The decision as between aeroplane and flying boat thus seems to depend largely on conditions at the terminals. The boat possesses the advantage that, using available harbours, construction of costly aerodromes is avoided. With increase in weight of wheeled aircraft, the cost of constructing runways capable of supporting the heavy wheel loads becomes high. In the case of oceanic or coast routes, harbours are at sea level and a high rate of climb is normally not necessary. The cost of fuel and supplies is generally lower at seaboard.

On the other hand, the use of boats is dependent on the availability of fog and ice-free harbours and on the ability to make blind landings on water. While blind alightings on water, using radio, have not been attempted, insofar as is known, there seems to be no technical difficulty involved. Without radio, dependence must be placed on an accurate and sensitive height indicator. With ample room, blind landings have been made by coming in on a flat glide until a weight hanging a known distance below the hull strikes the water.

The wheel undercarriage of aeroplanes, particularly of large size, is heavy and necessitates heavy structural members to take the landing loads. The working parts of the undercarriage require maintenance. If retractable, the retracting gear adds to the weight, complexity and mainnance of the undercarriage. In addition, for winter operation over the Atlantic, provision must be made for take-off on wheels from land and alighting on skis on ice or snow, or vice versa. Such provision can be made without serious sacrifice of efficiency.

The float seaplane is not considered suitable for the service. Compared with the boat, it is less seaworthy, has less reserve buoyancy (about 100-150 per cent, as compared with possibly 500 per cent for the boat) and is not capable of development to the large sizes possible with the boat. The seaplane is less efficient structurally and aerodynamically in the larger sizes.

Although, in discussions of the type of aircraft for an Atlantic service, the amphibian is generally dismissed as unsuitable, the figures tabulated in Table V for number 17, the Sikorsky S-43 amphibian, indicate that, both structurally and aerodynamically, the amphibian can be made quite efficient, which, coupled with its versatility in landing, amply justifies the amphibian receiving serious consideration. The weight of its landing gear should be little larger proportionately than the retractable undercarriage of land machines and it should possess the low structural weight and other advantages of the flying boat as is indicated by the plots for number 17 in Figs. 20-23.

Monoplane or Biplane

Present practice in commercial aircraft favours the monoplane. This is indicated in Tables V-VII and the corresponding figures. Insofar as is known, no large commercial biplane is now under construction anywhere. It is also worthy of note that the three major world records are held by monoplanes.

This question is largely associated with that of aspect ratio or span. The span of the equivalent monoplane (same induced drag) is greater than that of the biplane. For maximum economy, flying at maximum L/D aspect ratio is important, but its importance decreases with increase in operating speed and reduction in incidence below that of maximum L/D. Aspect ratio is also important in connection with climb and, for boats, take-off. The aspect ratio determined by these considerations has generally to be reduced, for practical reasons, such as housing, or in the case of boats, to provide tip clearance, in roll, on the water.

The parasite drag of the wing bracing of the biplane, even with high wing loading and few interplane struts, reduces the aerodynamic cleanliness as compared with the monoplane and, in consequence, for a given cruising speed, higher power is required, with greater fuel consumption (see Fig. 23).

At the same time, it appears from the weights of the few biplanes tabulated in Tables V and VI and plotted in Fig. 22, that the structure weight of biplanes is rather higher, instead of lower, than that of monoplanes.

The adverse effect on economy of a loss of aerodynamic efficiency is greater than that of the same relative increase in weight.

Figures 20 and 21 indicate that the transport efficiency of biplanes is generally less than that of monoplanes. For economy in long range operation, a good monoplane generally will be superior to a good biplane.

For flying boats, seaworthiness is important and from this standpoint the monoplane is the better. Its stability on the water, as when taxying, is greater since the side area is neither as large nor as high and the rolling moment is therefore less than for the biplane. Good wave clearance is provided by the high wing monoplane.

The cost of construction is largely influenced by the number of parts and hence generally the biplane structure, with its larger number of struts and fittings, will be higher, not only in initial cost, but also in cost of maintenance.

It is therefore evident that, for a service of the nature of that over the Atlantic, the monoplane is preferable.

Wing Loading

For economy of operation in long range commercial aircraft, high wing loading and moderately high power loading are essential. Generally speaking, the higher the wing loading, the closer does the cruising speed approach the speed of greatest aerodynamic efficiency. But with high wing loading, landing speeds are generally dangerously high and take-off difficult. For instance, with a wing loading of—

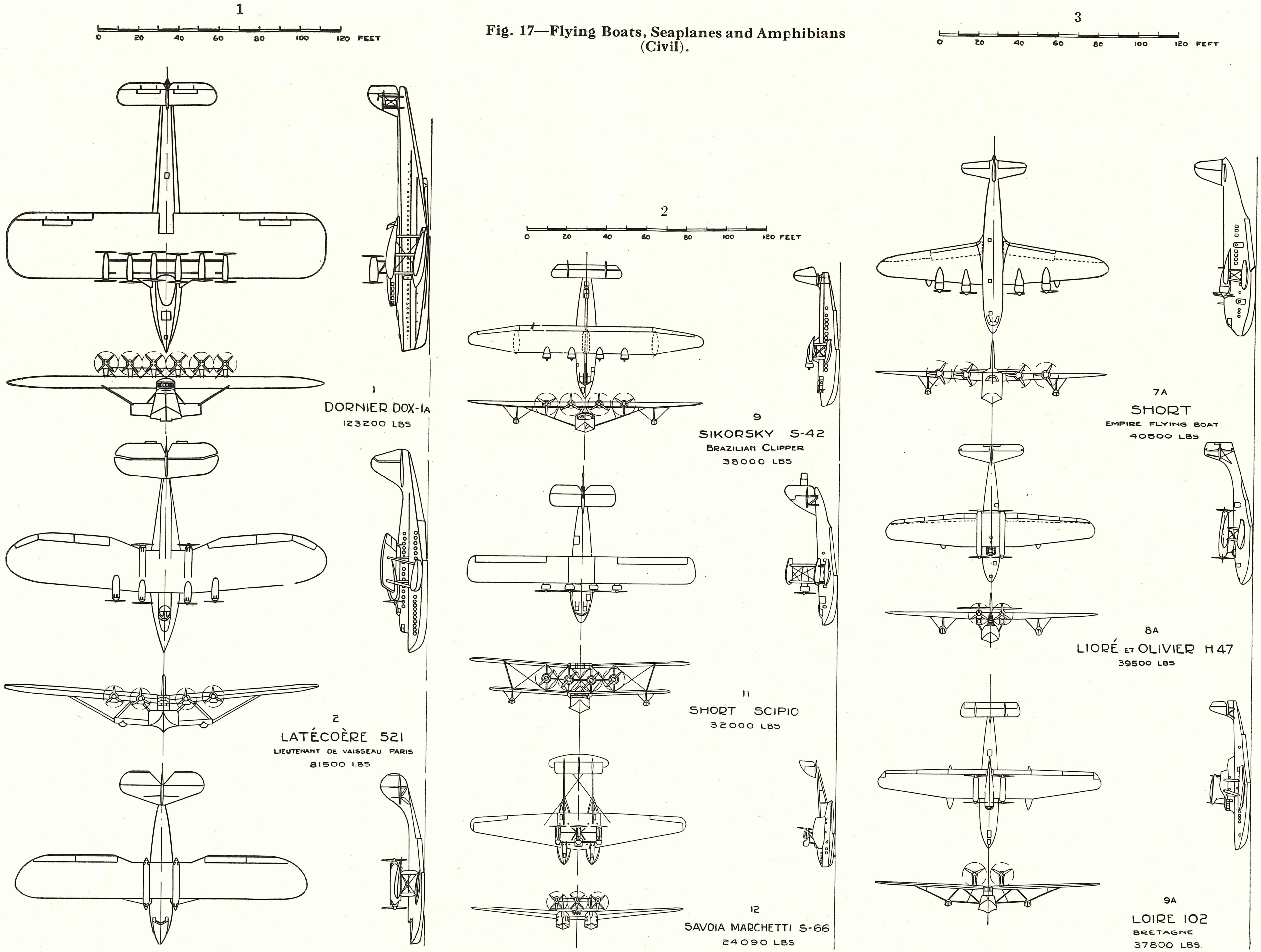
20 lb. per sq. ft., the stalling speed is 70 m.p.h. or 101 f.p.s.
30 lb. per sq. ft., the stalling speed is 85 m.p.h. or 125 f.p.s.
40 lb. per sq. ft., the stalling speed is 98 m.p.h. or 145 f.p.s.
50 lb. per sq. ft., the stalling speed is 110 m.p.h. or 162 f.p.s.

These speeds may be lowered and take-off and landing thereby improved by the use of slots, flaps and similar lift increasing devices and by wheel and air brakes. Variable pitch airscrews afford extra power for take-off and increased airscrew efficiency.

Because the weight of the fuel consumed in long flights is large, the gross weight and with it the wing and power loading, are much reduced at the end of the flight and the aircraft lands at a much lower speed than that at which it took off. In other words, the characteristics of the aircraft change during a long flight. If determined by the take-off conditions, the wing loading is unduly low at the end of the flight and the excess area over that required for alighting and the additional power provided for take-off reduce the pay load and range. In a general way, for efficient operation, the wing loading should be determined by conditions at the end of the flight and the power loading by the average cruising conditions during the flight.

Some of the foregoing points are illustrated by the performance curves of Fig. 24. The curves apply in a general way to a well designed modern long range flying boat, of gross weight 38,000 lb., rated power 2,800 hp. and a weight ratio of 2:1. Curves A (full lines) apply to the fully loaded aircraft with wing loading 28.6 lb. per sq. ft. and power loading 13.6 lb. per hp.; curves B (dotted lines) to the same aircraft, after flying at 160 m.p.h. a distance of 1,800 miles against a 30 m.p.h. head wind and using 14,000 lb. of fuel; curves C (dashed lines) to the aircraft with the same engine installation, when loaded up to a gross weight

Fig. 17—Flying Boats, Seaplanes and Amphibians (Civil).



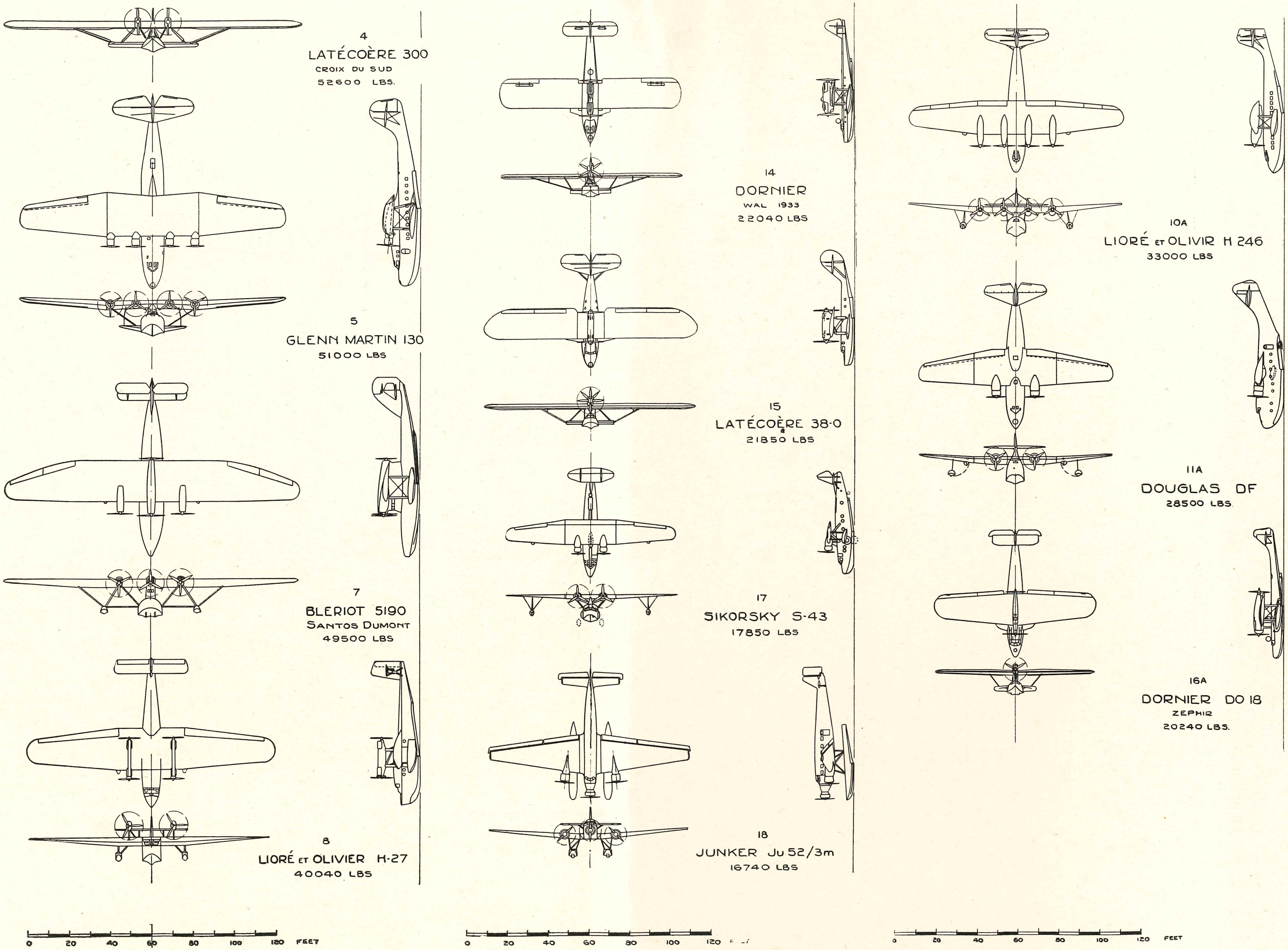
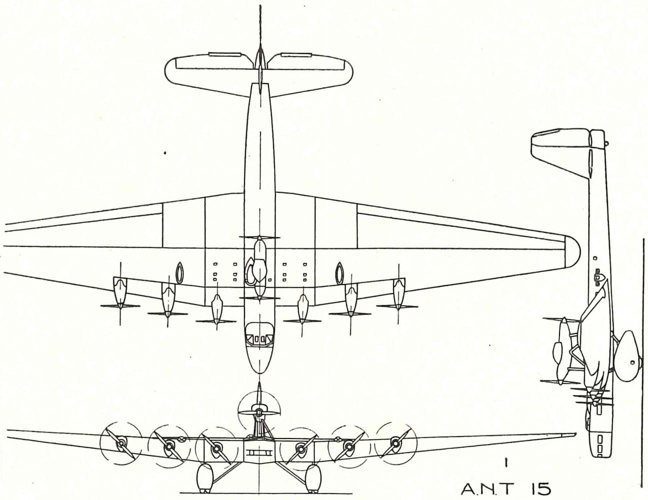

4
LATÉCOÈRE 300
CROIX DU SUD
52600 LBS.
5
GLENN MARTIN 130
51000 LBS
7
BLERIOT 5190
SANTOS DUMONT
49500 LBS
8
LIORÉ ET OLIVIER H-27
40040 LBS
0 20 40 60 80 100 120 FEET
14
DORNIER
WAL 1933
22040 LBS
15
LATÉCOÈRE 38-0
21850 LBS
17
SIKORSKY S-43
17850 LBS
18
JUNKER Ju 52/3m
16740 LBS
0 20 40 60 80 100 120
10A
LIORÉ ET OLIVIR H 246
33000 LBS
11A
DOUGLAS DF
28500 LBS
16A
DORNIER DO 18
ZEPHIR
20240 LBS.
0 20 40 60 80 100 120 FEET

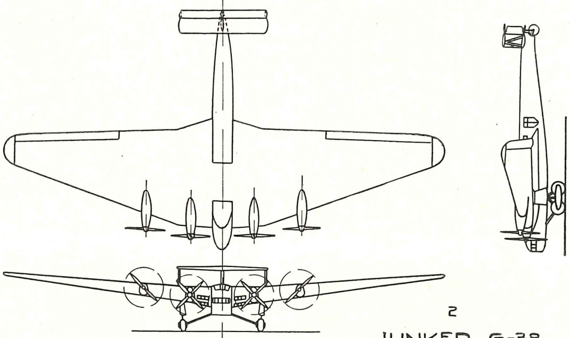
Fig. 18—Aeroplanes
(Civil)

0 20 40 60 80 100 120 FEET

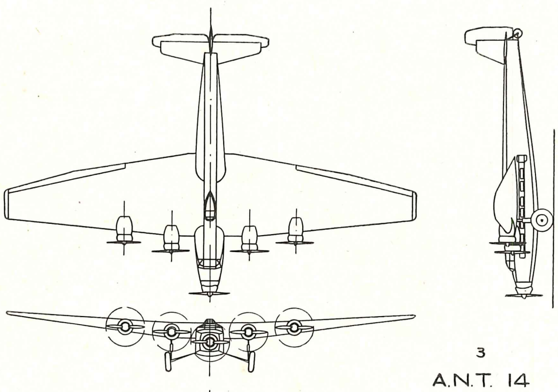
0 20 40 60 80 100 120 FEET



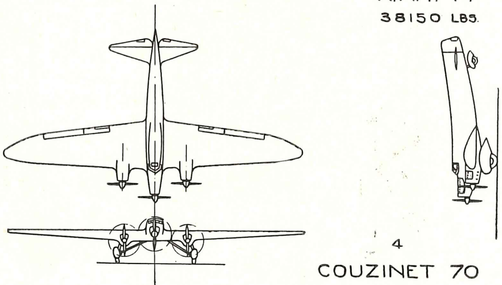
1
A.N.T 15
MAXIM GORKY
92600 LBS. (?)



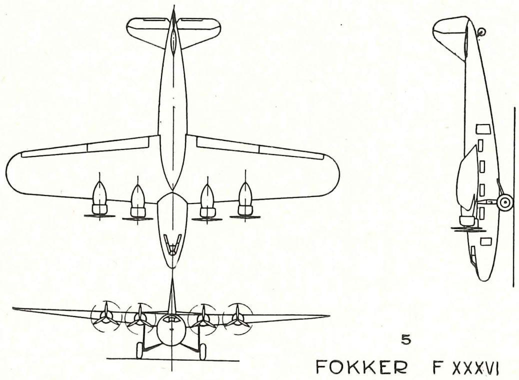
2
JUNKER G-38
52900 LBS.



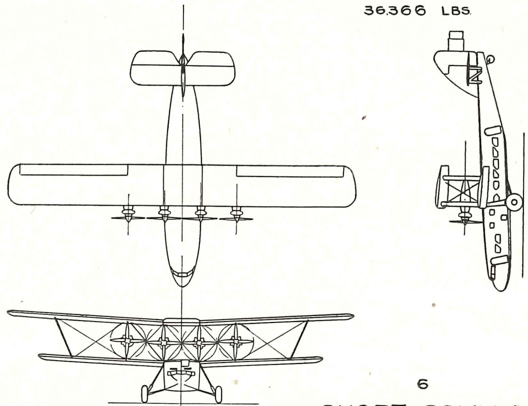
3
A.N.T. 14
38150 LBS.



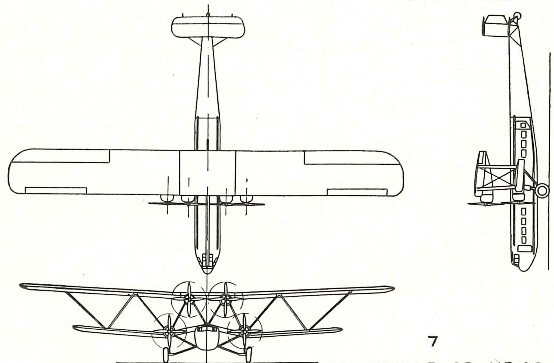
4
COUZINET 70
ARC-EN-CIEL
37000 LBS.



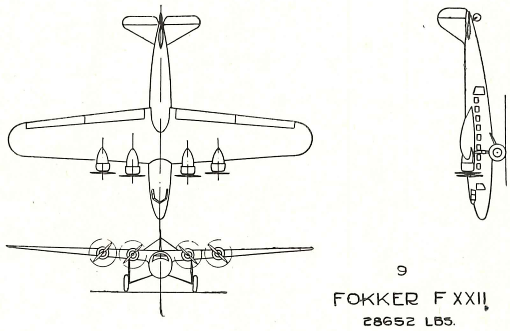
5
FOKKER F XXXVI
36,366 LBS.



6
SHORT SCYLLA
32000 LBS.



7
HANDLEY PAGE H.P. 42
30000 LBS.



9
FOKKER F XXII
28652 LBS.

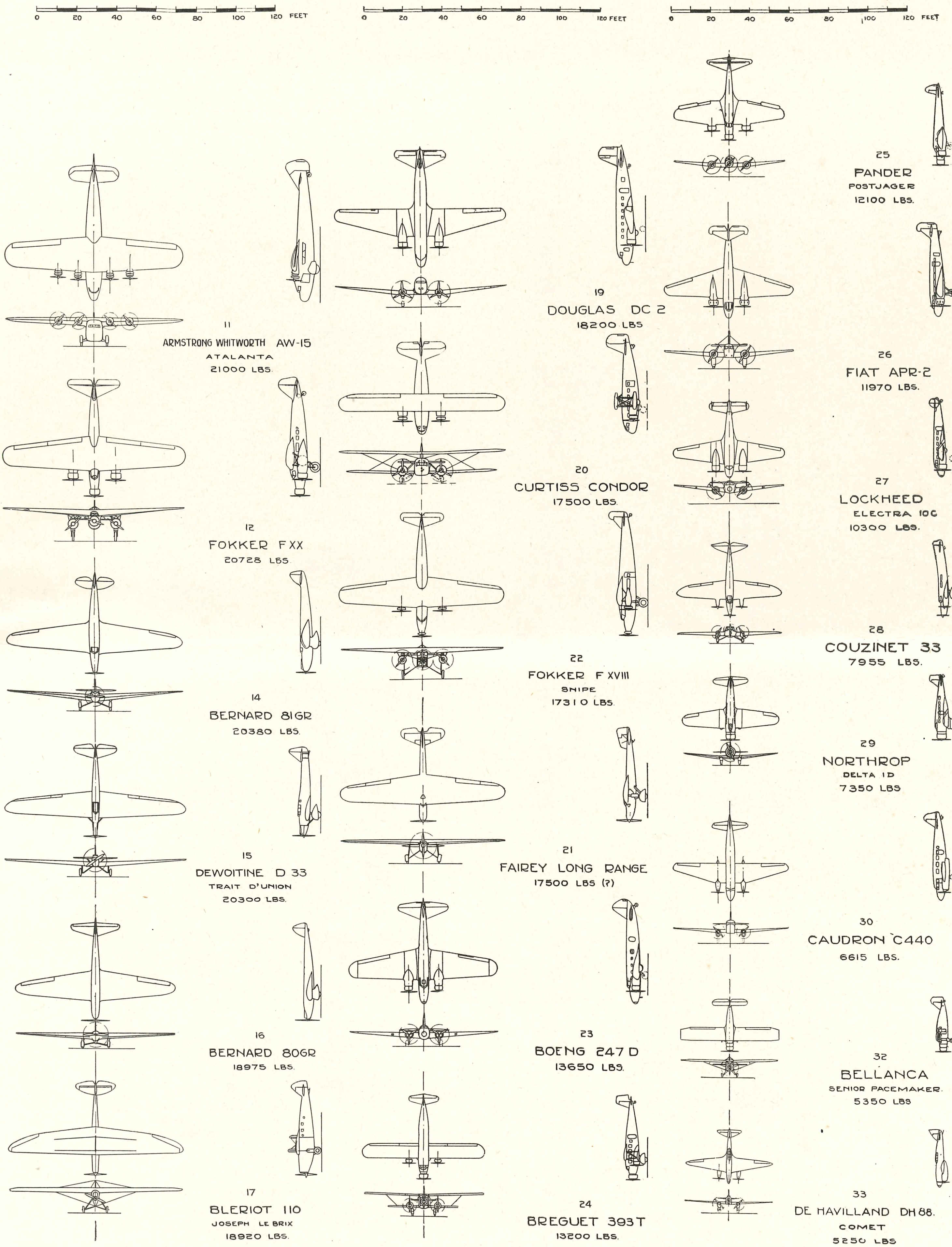
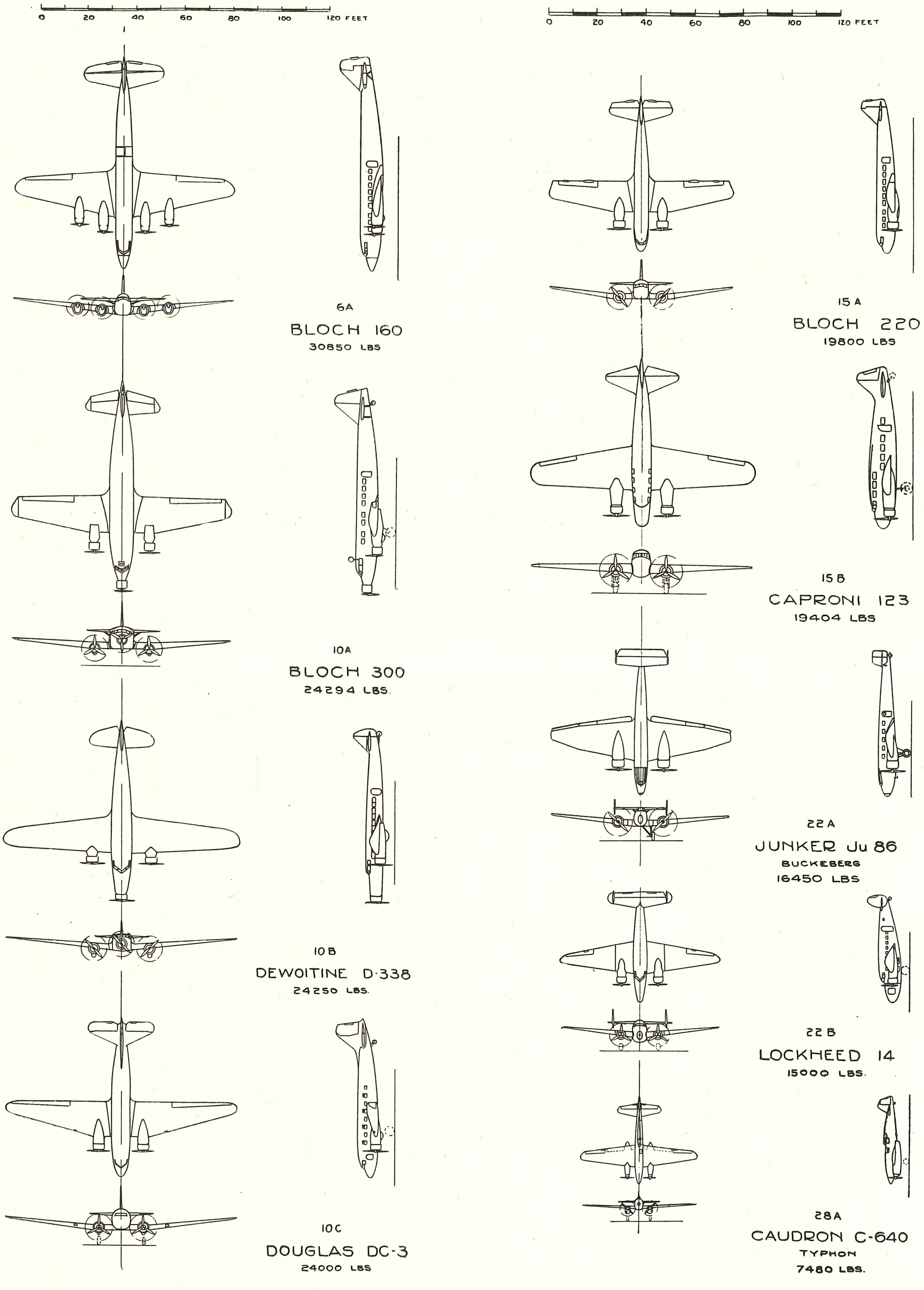

0 20 40 60 80 100 120 FEET
0 20 40 60 80 100 120 FEET
0 20 40 60 80 100 120 FEET
11
ARMSTRONG WHITWORTH AW-15
ATALANTA
21000 LBS.
12
FOKKER F XX
20728 LBS.
14
BERNARD 81GR
20380 LBS.
15
DEWOITINE D 33
TRAIT D'UNION
20300 LBS.
16
BERNARD 80GR
18975 LBS.
17
BLERIOT 110
JOSEPH LE BRIX
18920 LBS.
19
DOUGLAS DC 2
18200 LBS
20
CURTISS CONDOR
17500 LBS.
22
FOKKER F XVIII
SNIPE
17310 LBS.
21
FAIREY LONG RANGE
17500 LBS (?)
23
BOENG 247 D
13650 LBS.
24
BREGUET 393T
13200 LBS.
25
PANDER
POSTJAGER
12100 LBS.
26
FIAT APR-2
11970 LBS.
27
LOCKHEED
ELECTRA 10C
10300 LBS.
28
COUZINET 33
7955 LBS.
29
NORTHROP
DELTA 1D
7350 LBS
30
CAUDRON C440
6615 LBS.
32
BELLANCA
SENIOR PACEMAKER.
5350 LBS
33
DE HAVILLAND DH 88.
COMET
5250 LBS

Fig. 19—Aeroplanes
(Civil)



of 53,000 lb. corresponding to a wing loading of 40 lb. per sq. ft. and curves *D* (dot and dash lines) apply very roughly to an aircraft, otherwise the same, with the wing area reduced, to increase the wing loading to 40 lb. per sq. ft.

The curves illustrate the handicap on efficient operation resulting from the limitation imposed on wing loading by the requirement of safe take-off speed and the advantages that result from high wing loading. It is apparent, for instance, that, if this aircraft could be got into the air, it could fly with the wing area reduced to ½ or ⅓ of the normal area.

Roughly, for condition *C*, the cruising speed is 150 m.p.h., time of flight fifteen hours and fuel burned 15,000 lb., leaving a disposable load in excess of fuel of 11,500 lb., assuming the same weight ratio. For condition *D*, the cruising speed is 180 m.p.h., time of flight twelve hours, fuel consumed 12,000 lb. and disposable load, over and above fuel, 7,000 lb., assuming no change in structural weight. The disposable loads, less fuel, carried per horsepower, for conditions *A*, *C* and *D* are 1.8 lb., 4.1 lb., and 2.5 lb. and the transport efficiencies 0.540, 0.710 and 0.610 ton miles per hour per horsepower respectively.

The higher the wing loading, the smaller is the wing area and the size of all other elements depending thereon—tail area, length of fuselage, etc., and the smaller and lighter the aircraft. Thus, increasing wing loading reduces structural weight thereby improving the transport efficiency.

Increase in wing loading reduces the ceiling and rate of climb. For long range oversea operation from large well located permanent airports or protected harbours, a high rate of climb is not essential. The adverse effect on take-off resulting from reduced rate of climb can be nullified by catapulting and reduction in ceiling can be compensated for by supercharging the engines.

For service over the North Atlantic, good airworthiness is a prime requisite. The higher the wing loading, the less the effect of a vertical gust or squall. Highly loaded aircraft now in service confirm theory in that their flight is smooth and easy and their control characteristics in stormy weather are good. In addition, the smaller wing permitted with high loading is advantageous in flying boats when afloat.

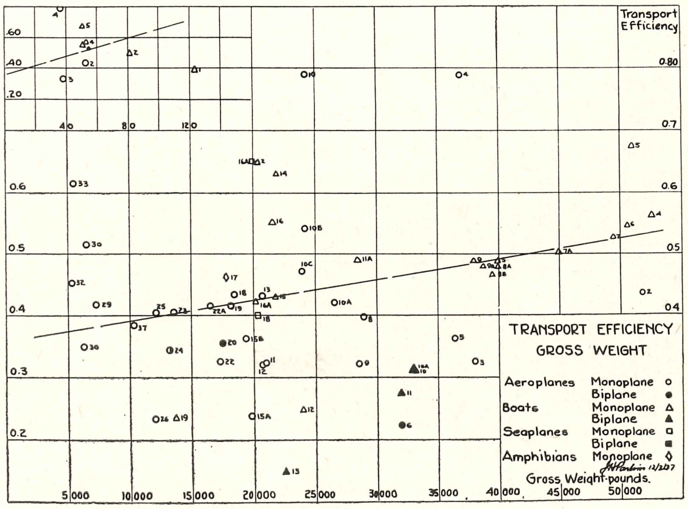


Fig. 20—Transport Efficiency—Gross Weight

Thus, with high wing loading, the maximum and cruising speeds are higher, range and pay load are increased, weight of structure is reduced and efficiency of transport, airworthiness and safety are improved. The accompanying loss in ceiling can be compensated, the lower rate of climb can be accepted and the increase in take-off and landing speeds can be counteracted. For these reasons, the aircraft for the transatlantic service should be designed with a high

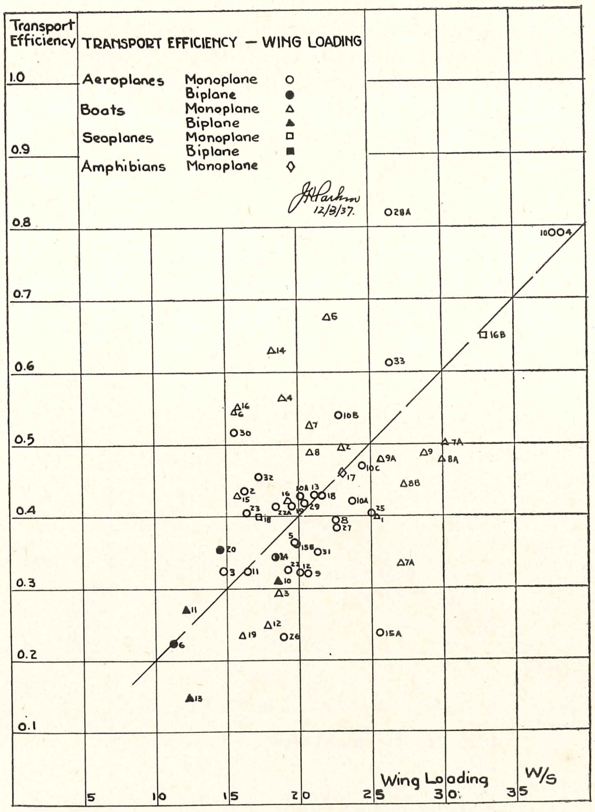


Fig. 21—Transport Efficiency—Wing Loading.

wing loading and a loading of 40 to 50 lb. per sq. ft. is suggested.

Power Loading

The performance characteristics influenced by the power loading are speed, maximum and cruising, take-off, climb and ceiling. For commercial operation, the first two are usually the determining considerations. With an assisted take-off, the power loading will depend on the cruising speed and altitude and the aerodynamic fineness of the aircraft.

The graphs of Fig. 24 indicate the way in which speed is increased by increase in power and reduction of drag, and Fig. 23 illustrates the variation of speed with power loading.

The higher the power, the greater the weight of the power plant (engine, accessories and fuel) and the smaller the pay load. At the same time, the installed power must provide for operation at a cruising power below rated power and a margin of power to take care of failure of one or more engines.

With a high cruising speed, fixed by the service timetable, if the power loading is to be reasonably high and economy of operation attained, the drag of the aircraft must be reduced to a minimum.

Aerodynamic Fineness

An analysis of the factors contributing to the total drag of an aircraft indicates that, for economy at high speeds, the wing loading must be high and the parasite drag low.

The aerodynamic cleanness of an aircraft is largely bound up with the structural design and it is necessary from an economic standpoint to balance structure weight against drag. An increase in weight must be accompanied by an increase in *L*/*D*. Very generally a reduction in drag is more effective in this respect than reduction in weight of structure.

The cantilever monoplane permits the cleanest aerodynamic design and, as already seen, the gain in this respect is not offset by an increase in structural weight.

Similarly, the lower drag of liquid cooled engines must be balanced against their somewhat greater weight. From this point of view, the housing of the engines wholly within the wings is desirable.

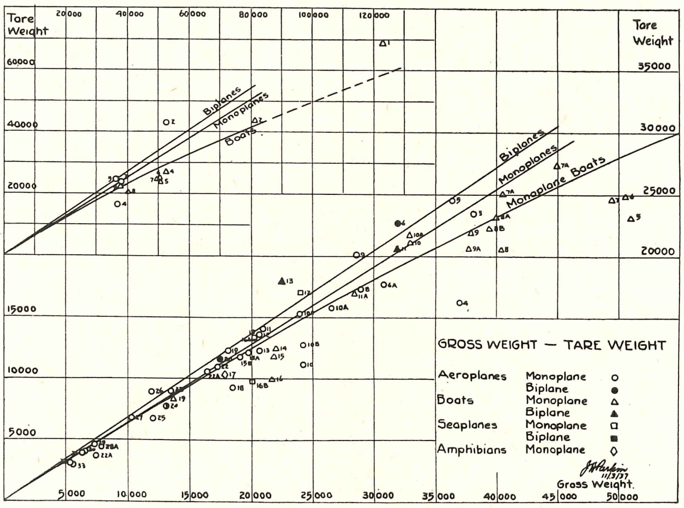


Fig. 22—Gross Weight—Tare Weight.

Retractable undercarriages, flush riveting of metal skins and similar means for the reduction of drag should all be employed.

While there is still room for improvement in aerodynamic cleanness, modern commercial aircraft, both aeroplanes and flying boats, possess very high values of L/D, ranging from 12-15. Notable performance and high transport efficiency have been attained with some of the aircraft listed in the tables, largely as a result of careful attention to aerodynamic cleanliness.

Structure Weight

The greater the ratio of gross to tare weight, i.e., the lower the structure weight, the larger the fuel and pay load which may be carried. Reduction of the weight of the structure involves both the type of construction and the size of the aircraft and, at the same time, the drag. With certain types of construction, low structure weight is associated with high drag. As already seen, high wing loading leads to a reduction in weight.

The weights of Tables V-VII are plotted in Fig. 22, excluding those of machines specially designed to establish records and it will be seen that there is some indication, particularly for flying boats, that the structure weight is proportionately less the larger the aircraft. There may be a limit to this condition, but it is not yet evident.

Power Plant Efficiency

Since range varies inversely as the fuel consumption, maximum range and economy result from the minimum consumption per brake horsepower per hour. This specific fuel consumption depends on a number of factors, including—

1. The power plant, its type, condition, operation and control.
2. The speed of flight.
3. The altitude of flight.

Type of Power Plant

Economy of transportation is influenced by the power plant, not only as a result of its effect on the specific fuel consumption, but also, since the power plant contributes a large part of the aircraft weight, through its influence on the gross weight of the aircraft. For economy, a power plant of low specific weight and low specific consumption, i.e., low weight of engine and fuel, is required.

The ratio of the fuel load to pay load varies with the length of the flight. The longer the flight, the less the pay load that can be carried. Fuel load and pay load are, in a sense, interchangeable within a given total disposable load.

At the present time, the electrical ignition gasoline engine, either air or liquid (or steam) cooled is used, with a few notable exceptions, for aircraft propulsion. Gasoline engines, developing up to 1,000 hp. and more, weighing less than 1.5 lb. per hp. and having specific consumptions of fuel and oil of 0.50-0.55 lb. per hp., are in regular production. At the same time, these engines are daily proving themselves possessed of adequate reliability, long life and low maintenance.

The present high state of development has resulted from improvements in design, in materials, in production methods and in fuels. Increased speed of rotation, higher compression ratios and supercharging have raised the output per litre of the cylinders of normal engines to 30-40 hp.

Although the specific consumption of fuel and oil of the liquid-cooled motor is slightly less than that of the corresponding air-cooled (averaging 0.52 as compared with 0.54 lb. per hp. per hr. and is still lower with glycol cooling), its specific weight, including the cooling system, is higher—2.0 lb. per hp.—compared with 1.5 lb. per hp. However, its true weight handicap is less than these figures indicate, if due allowance is made for the weight of the cowling, baffles, additional oil-cooling, etc., so necessary in modern high power air-cooled engines. On a basis of the total weight of the power plant, including fuel and oil, using the foregoing figures and neglecting the effects of differences in aerodynamic resistance, a flight of about twenty-five hours is required before the liquid-cooled motor overcomes its weight handicap. Actually, for the reasons given, a shorter time will be necessary.

While the difference in drag between the modern cowled radial air-cooled engine and an in-line liquid or steam cooled engine, with its radiator or condenser, is

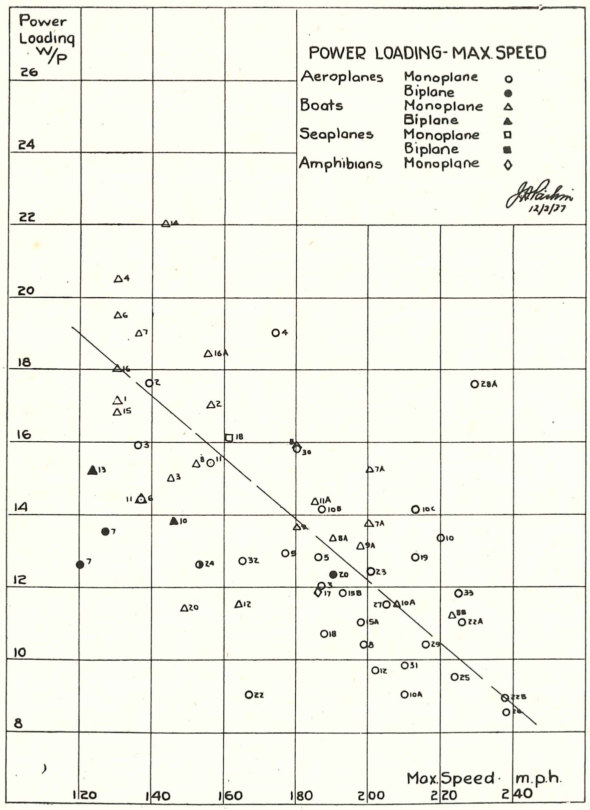


Fig. 23—Power Loading—Maximum Speed.

less than formerly, the advantage still rests with the liquid-cooled plant.

The former handicap of the liquid-cooled installation of lack of reliability due to "plumbing" troubles no longer exists, with the modern simplified cooling system; the air-cooled motor is acquiring an analogous handicap in the intricate system of adjustable cowling, intercylinder baffles and special oil cooling, without which high output cannot be maintained and is, at the same time, losing its former advantage of simplicity.

It is significant that, insofar as is known, all long distance world records have been made by aircraft powered by liquid-cooled motors.

For the initial transatlantic service, it is probable that the air-cooled engine will be used, but it is believed that, before the service has been long in operation, aircraft will be used in which the power plant will be housed in the wings or body, using, if air-cooled, forced air circulation through ducts. For such an installation, the radial air-cooled engine is not suitable. If liquid-cooled motors are used, ducted radiators will be employed. In either case, reduced drag and increased accessibility will result and the cooling medium, or air, heated therefrom, in the case of liquid-cooled motors, will be used for cabin heating and ice prevention.

It is further anticipated that the limitation imposed by the exhaust valve on any further large increase in specific output of the poppet valve engine, coupled with other advantages being demonstrated by this motor, will result in the rapid introduction and wide use for commercial service, particularly of the kind under consideration, of the sleeve valve motor. The low fuel consumption (i.e. 0.43 lb. per hp. per hr. at cruising power, recorded for the Bristol Perseus engine), is an important advantage of the sleeve valve motor for long range commercial service.

For commercial service, the compression ignition engine, because of its numerous advantages, is attractive and especially so for a service over long non-stop stages where its low specific consumption is able to offset its present handicap of high specific weight.

Comparison of the principal aviation compression ignition engines with modern electric ignition gasoline engines of 800-1,000 hp. yields the average figures for specific consumption and weight given in Table VIII. An allowance is made of 0.4 lb. per hp. for the weight of the cooling system of liquid-cooled gasoline engines and 0.3 lb. for that of compression ignition engines. The weight of the tankage is taken as 0.8 per cent of the fuel weight.

The weight of the complete plant for a flight of X hours, neglecting effects of reduction in gross weight as fuel is consumed, is shown in the last column. From these figures, it will be seen that the compression ignition engine weighs less than the gasoline engine for flights of more than six to seven hours and possibly less if allowance is made for the better maintenance of power at height of the compression ignition engine. For a 1,000 hp. aircraft

TABLE VIII

COMPARISON OF GASOLINE AND COMPRESSION IGNITION ENGINES

Type of engine	Specific weight on nominal B.h.p.		Specific consumption on nominal B.h.p.	Weight of power plant complete with fuel for X hours
	Dry	With cooling system	Fuel and oil	
Air-cooled				
Gasoline	1.5		0.54	$1.5 + 0.58X$
Compression ignition	2.5		0.40	$2.5 + 0.43X$
Liquid-cooled				
Gasoline	1.6	2.0	0.52	$2.0 + 0.56X$
Compression ignition	2.6	2.9	0.38	$2.9 + 0.41X$

on a flight of twelve hours, the compression ignition engine will permit, on the foregoing basis, an increase in pay load of 800-900 lb. over that with a gasoline engine.

In view of the foregoing, it is difficult to understand the apparent lack of interest in the compression ignition engine. If the same effort had been given to the compression ignition engine as has been devoted to the development of the gasoline engine, the superiority of the compression

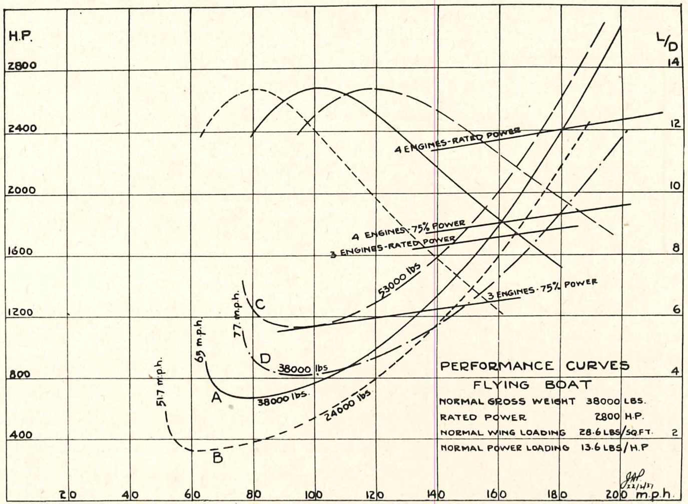


Fig. 24—Performance Curves, Flying Boat.

ignition engine for commercial service would be more marked. While compression ignition engines will not likely be used on the initial transatlantic services, except that of the D.L.H., it is considered that their ultimate use for this work is inevitable.

Power Plant Operation and Control

Overall economy of operation depends, not only on fuel consumption, but also indirectly on the life of the engine and frequency of overhauls. Aircraft engines will not run indefinitely at full power without damage. The longer and more frequent the periods of high power operation, the more frequent the overhauls. It is therefore customary to cruise with the engine throttled to from 60-75 per cent of full power to prolong its life, lengthen the periods between overhauls and afford a margin of power for use in the event of failure of one or more engines in a multi-engined aircraft. The engine is tuned for minimum specific consumption at this reduced cruising power.

It should be noted that this reduction in power can be secured at full throttle through the equivalent throttling resulting from the reduced density at high altitudes, with at the same time, a gain in speed. Thus, at full throttle at constant r.p.m. at 13,000 ft., the power is reduced to 60 per cent and at 8,000 ft., to 75 per cent of rated power.

The specific consumption varies with mixture, throttle and altitude. Consumption can be appreciably reduced by operating on lean mixtures, but it is normally not possible to operate on a mixture much leaner than the theoretically correct. However, engines can be safely operated on mixtures leaner than is customary, especially when throttled, and liquid-cooled motors can, in general be operated on leaner mixtures than air-cooled.

The specific consumption varies but little with throttle in the region of the minimum, but increases appreciably for full throttle and at small throttle openings.

The more economical the operation of an engine, the less is economy affected by height. Under present conditions, there is possibly a slight gain in economy at altitude in normally aspirated engines and also in supercharged engines up to some altitude below the rated height.

Theoretically, the reduction in consumption is about 2 per cent for normally aspirated engines and 3 to 4 per cent for supercharged engines at 15,000 ft., but this gain is largely offset by the less favourable carburation and distribution conditions at altitude.

As with manual control, fuel consumption may vary as much as 40 per cent for different pilots under the same conditions, automatic controls are now employed where economy is important. The average figures for consumption used in Table VIII would be somewhat lower with automatic controls or with unusually careful manual control. Actual consumptions in the neighbourhood of 0.4 lb. per hp. per hr. at ⅔ power have been obtained in long distance flights with liquid-cooled motors and a figure of 0.37 is theoretically possible.

Automatic controls and constant speed airscrews are used on the Sikorsky S-42 flying boats and specific consumptions as low as 0.42 lb. per hp. per hr. are reported for the Pacific flights.

Supercharging

The drop in power with altitude in a normally aspirated engine (power at 13,000 ft. about 60 per cent of that at sea level) is offset by supercharging. The supercharger maintains the air supplied to the engine at constant pressure (rated boost) up to the limiting or rated altitude beyond which the pressure falls with altitude in the normal way. A rated altitude of 15,000 ft. is generally considered to be about the limit for a single stage centrifugal supercharger (1.85:1 compression ratio).

While the power required to drive the supercharger increases (7.5 per cent at 12,500 ft.) and the thermal efficiency of the engine decreases, there is an actual increase of about 1 per cent per 1,000 ft. in the power developed by a supercharged engine at constant boost and r.p.m. up to rated altitude due to reduction in exhaust back pressure. At the same time, the fuel consumption is increased and the engine weight is greater by the weight of the supercharger.

The alternative to supercharging is the provision of an oversize engine such that the reduced power developed at altitude equals that required. The weight of the engine with supercharger is probably less than that of the oversize engine, but its fuel economy is also lower. On the whole, the power necessary for high speed operation at altitude can be best attained by supercharging. In addition, supercharging enables extra power to be developed at sea level to assist take-off.

For operation of the Atlantic service, cruising at 180 m.p.h. at an altitude of about 12,000 ft., as suggested later, it is considered that moderately supercharged engines of rated altitude of 5,000-6,000 ft. should be used. The throttling effect of reduction in air density above this height will reduce the power at full throttle to a cruising power of about 75 per cent of full power.

Variable Pitch Airscrews

For the conditions of high speed, high loading and high altitude suggested for the service, V.P. airscrews are necessary, especially with geared and supercharged engines. The primary consideration for the service is efficient operation at cruising speed and altitude. With fixed pitch airscrews designed for this condition, the loss in efficiency and power at low speeds during take-off and climb is prohibitive. With the V.P. airscrew on the other hand, the pitch can be adjusted to suit both take-off and high speed conditions. The engine therefore holds its speed and power and a large increase in thrust for take-off, 100 per cent or more in average thrust, is provided with V.P. airscrews, particularly with geared and supercharged engines.

The V.P. airscrew permits the engine speed to be controlled by the pitch of the blades as well as by the throttle and, in fact, the most recent development is the constant speed airscrew which, if left alone, maintains constant speed, although the speed may be controlled by the pilot.

Thus, operating at high altitude and full throttle, the normal cruising power results and the engine speed can be held to cruising r.p.m. by the V.P. airscrew, thereby increasing cruising speed.

In the event of engine failure in a multi-engined aircraft, the drag of the idle airscrew can be reduced and the speed and power of the active engine maintained, thereby enabling flight to be continued even with heavy load. This feature is particularly marked in the case of tandem engines. Tests indicate that fuel consumption at a given speed is less with V.P. airscrews than with an equivalent fixed pitch airscrew.

Evidently the V.P. airscrew is advantageous for the high loading, high speed and other conditions of an Atlantic air service.

Speed

The speed of flight is determined by two principal considerations, economy of operation and the requirements of the service.

The chief advantage possessed by the aeroplane compared with the fast liner and airship for transatlantic service is speed and, if this advantage is to be appreciable, the elapsed time between terminals must be low and the cruising speed consequently high.

The schedule already suggested is based on a cruising speed of not less than 180 m.p.h.

As previously indicated, for high cruising speed, clean aerodynamic design must be combined with one or more of high wing loading, high power and high altitude of flight. The possibilities and limitations of these alternatives have already been briefly reviewed.

Ordinarily, the most economical speed is too low for practical commercial operation. Also, as fuel is consumed during flight, the weight of the aircraft decreases and the speed of maximum efficiency decreases in proportion to the square root of the gross weight, necessitating a progressive decrease in r.p.m., further throttling and increase in specific consumption. On the other hand, the most efficient speed increases with altitude and the effect of decreasing weight can be offset by increasing altitude to maintain constant speed.

To minimize the adverse effects of winds on the flying schedule, the speed must also be high since the higher the speed, the less the effect of winds.[25] This is clear from the following expression for the effective speed or speed made good. For a flight speed of V and a wind speed v m.p.h., at an angle θ to the course, the effective speed is:

$$V_e = \sqrt{V^2 - v^2 \sin^2 \theta} + v \cos \theta$$

Aside from schedule requirements, a high flight speed is advantageous against a head wind by reducing the time during which the handicap is suffered while, with a favouring wind, the desirable speed is one near that for minimum power, permitting the aircraft to benefit a longer time. The most economical speed is increased by head winds and decreased by tail winds.

Under the foregoing limitations, maximum practical economy is attained by adopting as high a wing loading as permissible and designing and adjusting the engine-airscrew combination to operate with minimum fuel consumption at the speed demanded by the service.

Altitude of Flight

In the selection of the altitude of flight to be used in the service, there must be considered, economy (i.e.,

[25]In this respect also, ease of navigation is increased.

altitude for most miles per gallon), navigation and weather, personnel and passengers and other factors.

Flying at the altitude of maximum aerodynamic efficiency, the true airspeed and horsepower must be increased, at altitude, to compensate for the decrease in air density. The increase is inversely proportional to the square root of the air density, neglecting the effects of slip stream variation. The effect of altitude on the speed of maximum efficiency is similar to that of wing loading, the increase in the speed at 10,000 ft. being about equal to an increase of 1/3 in loading.

At constant L/D, i.e., constant indicated airspeed, economy of flight is dependent only on the specific fuel consumption. The effect, if any, of altitude will be that due to the variation of consumption with height and consumption may decrease slightly with altitude.

On the other hand, to maintain a given true airspeed at altitude (higher than that of maximum aerodynamic efficiency), the power necessary is less than at sea level since the power required depends on the drag, which, in turn, varies inversely as the L/D and, as the incidence must be increased to compensate for decrease in air density, the L/D increases as the angle of maximum L/D is approached. Under these conditions, the power required decreases rather more rapidly than the air density. The air speed will remain nearly constant if the altitude is increased, as the weight decreases with consumption of fuel, to maintain a balance between cruising power of the engine and the power required.

From the standpoint of economy then, the service should be operated at a high altitude.

Lacking definite knowledge concerning upper air weather conditions over the Atlantic, such as the height of storms, it is not possible to predict the best altitude from a meteorological standpoint.

Experience indicates that the air pressure in the cabin must be increased over that outside if passengers are to be carried at altitudes above 12-14,000 ft.

On the whole, it is considered that, with the present state of development of aircraft and equipment, the most favourable altitude of flight for the initial transatlantic service will be about 12,000 ft., for which satisfactory and relatively light superchargers are now developed, at which special provision for the crew (and passengers) is not necessary and which probably exceeds the height of most storms.

Precautions against Icing

The danger due to the formation of ice is peculiar to aircraft and is, perhaps, the most serious meteorological hazard of the transatlantic air service. The extent and seriousness of the hazard is as yet unknown. It has already been reported by stunt pilots and, with little doubt, has been responsible for the failure of many attempted transatlantic flights.

Ice may form on aircraft in any weather and in any cloud in which the temperature is below freezing. The character and effects of ice formation on aircraft and the conditions favourable to icing are dealt with in Appendix XII.

It is fortunate that serious deposits occur only in some form of visible moisture since the pilot is thereby given visual warning provided he knows the air temperature. The aircraft therefore should be equipped with a distant reading thermometer with metal shield and located outside the zone of influence of the airscrew; and with lights for the detection of visible moisture at night.

Avoidance

The best safeguard against the ice hazard is avoidance of the ice-forming region through accurate meteorological prediction of the location and extent of the region. The number and complexity of the factors involved in icing, the difficulty of observation and consequent lack of information renders prediction in particular for the transatlantic service very difficult.

Heaviest icing usually occurs in long extended zones associated with "fronts," i.e., air mass boundaries. Synoptic maps give information concerning such fronts. This is another reason for the provision of the most complete weather maps and forecasts possible for each flight.

The most dangerous condition occurs in low cold air, when warm air meets and over-rides a stationary low flat air mass, or a wedge of cold air pushes under a warm air mass. The former is the condition of a change from frost to thawing weather and the latter from mild to cold. Icing due to supercooled rain is less common in the latter case.

Temperature is the principal criterion of the probability of icing. Lacking upper air information, the air temperatures at altitude must be estimated from surface conditions, assuming a suitable lapse rate. The latter depends on many factors: time of day, season, latitude, surface (land or water) cloudiness, wind, pressure distribution and precipitation. It averages 1 deg. per 328 ft.

Determination from the ground of the size of cloud droplets, which has a bearing on the kind of ice formed, is difficult. An incipient rain condition indicates large droplets. A corona, if small, i.e., close to sun or moon, indicates large droplets. A halo indicates clouds composed of ice spicules.

Low pressure areas being generally associated with cloudiness and precipitation, are usually more favourable to icing conditions than are high pressure areas. Conditions favourable to icing are probable to the leeward of large bodies of water and over high terrain.

When very damp cloud air at subfreezing temperatures is encountered and icing is probable, as a result of cold air inflow or over-running, an attempt should be made to climb above the clouds. This is often successful at heights of 10-13,000 ft., although, in most cases, an altitude of 16,000 ft. is required and even this may not be sufficient. While climbing, the zone of frost should be avoided to escape icing and possible reduction in ceiling of the aircraft.

Ice deposits from freezing rain can often be removed or prevented by flying in the inversion usually existing above such rains.

If ice forming fronts must be crossed, it should be done at right angles, to shorten the period of icing.

Prevention

While avoidance of the ice forming zone, through meteorological prediction, is the best safeguard, with existing knowledge, such prediction is uncertain. Preventive measures on the aircraft are therefore necessary to cope with unexpected, heavy and rapid icing. Also, the extent of the zone and the service schedule may be both such as to necessitate flight through the zone.

Many preventive methods and devices have been suggested or tried. Very few have been found reasonably efficacious and have been adopted in service.

The use of coatings of so-called waterproof materials, such as oil, grease and wax, to lower the adhesion of ice has been found ineffective. Resistance to penetration of water at ordinary temperatures is no indication of resistance to ice at or below freezing, in fact, the reverse may be the case.

The adhesion of ice can be definitely lowered, although the rate of formation is little affected, by providing on the surface, a substance which, mixed with supercooled water, lowers the freezing point sufficiently to maintain a liquid boundary layer. Because of their more rapid rate of mixing, liquids miscible in all proportions with water are superior to soluble solids for this purpose, but they must be protected

from the scrubbing action of the air and rain. Specially processed rubber and leather have been found the best means of retaining the liquids on the surface.

In the so-called "overshoe" developed in the United States, the coating of specially processed rubber has built into it, for wings, three air tubes and for tail surfaces a single tube weaving back and forth. The overshoe is held to the leading edge of metal wings by means of threaded rivets. Air at 5 pounds pressure is supplied to the tubes through distributing valves in such a way that the tubes are alternately inflated and deflated about every 40 seconds, thereby first cracking the ice, then lifting it so that it is caught by the air and carried away, owing to the reduced adhesion.

The complete installation weighs about 75 lb. There is negligible effect on performance except when the tubes are inflated. The rubber is said to require renewal about once a year. Originally, the rubber was impregnated with pine oil, but the oil has been found unnecessary. The overshoe is widely used on commercial aircraft in the United States and Europe.

In the "anticer" developed at the Royal Aircraft Establishment in England, a porous outer surface of specially tanned leather is employed, to which ethylene glycol alone or mixed with 10 per cent of ethyl alcohol is fed under slight pressure through a perforated tube. The liquid is spread by an under layer of cotton and saturates the leather. As fast as the ice is formed, that next the leather is melted by the liquid, lowering the adhesion and the ice is blown off by the air. The flow of fluid may be varied to suit conditions and is normally about 1½ pints per hour. The anticer is applied to the leading edges of wings and tail surfaces. It is light, easily fitted and has little effect on performance. It has been found effective in service.

Airscrews may be protected in a similar way by means of a porous leather cover over the boss and inner portion of the blades to which the glycol is fed by means of a slinger ring on the back of the hub.

A somewhat similar arrangement has been developed in the United States. The airscrew is fitted with an oil impregnated rubber covered spinner. An 95:15 alcohol glycerine mixture is fed by means of a slinger ring to tubes which deliver the liquid, behind the spinner, to the leading edge of each blade and the liquid spreads over the blade under the combined action of centrifugal force and air flow. The increased centrifugal force, combined with a certain amount of flexing and heat generated in overcoming viscous drag, tend to keep the blade tips free of ice.

In addition to icing under conditions already mentioned, ice formation in the carburettor and induction system, due to cooling caused by evaporation of the fuel, may have serious consequences. Carburettor icing depends on the humidity, temperature and pressure. In an unheated carburettor, dangerous accumulations are probable with high humidity for intake air temperature between 15 and 65 deg. F. It may be prevented by heating the intake air or, more effectively, by heating the carburettor by jacketing. Another effective method is by the addition of alcohol (ethanol and methanol) to the fuel in the carburettor, under the control of an ice detector, which admits alcohol when ice begins to form.

Freezing of radiator shutters is best prevented by placing them back of the radiator.

Airspeed heads are now commonly protected from ice by electric heating. Venturis are replaced by vacuum pumps and windmill drives by positive drives from the engine.

The use of heat for ice prevention is attractive. The large amount of waste heat available (about ⅔ that in the fuel), the fact, proved in hydro-electric plant practice, that the temperature of the surface need be only a minute fraction of a degree above freezing to prevent the adhesion of ice, and the further fact that icing most frequently occurs with temperatures close to the freezing point, are factors favourable to the use of heat.

The amount of heat required will depend upon the meteorological conditions, the wing and the speed. The rate of heat transmission through the brass covering of a Clark Y wing, at 80 m.p.h., has been found to vary from 27 near the leading edge to 19 B.t.u. per sq. ft. per hr. per deg. F. temperature difference near the trailing edge.

Utilization of waste heat from the power plant is considered practicable only for all metal monoplanes. There are a number of promising possibilities.

With liquid cooled (glycol) or steam cooled engines, the jacket heat may be used in wing and tail surface radiators, or possibly leading edge radiators. The reduced drag of the radiators may be more than offset by the greater weight and plumbing difficulties.

The piping of the exhaust gases to a detachable leading edge is perhaps the most direct method of utilizing the heat in the exhaust, but difficulties are involved, including corrosion due to acids and high temperatures, thermal expansion and proximity to wing fuel tanks. The probable reduction in exhaust noise is an advantage of the method.

There is some indication from tests that heating the leading edge is effective only in preventing the accumulation of ice in that region, and that ice will continue to form on the unheated after portion of the wing.

It has been suggested in the National Research Laboratories, Ottawa, that icing of the wings and of the airscrew might be prevented by piping exhaust gases to a leading edge section of the wing and discharging them therefrom through a properly located narrow slot parallel to the span in such a way that a sheet of hot gases flows back over the wing surface. The blades of pusher airscrews sweeping through this sheet of hot gases may have their temperature raised sufficiently, in combination with the temperature increase due to viscous drag, to prevent ice formation.

Rough preliminary tests of such an arrangement made early in 1935 in the National Research Laboratories gave promising results. The wing surface from leading to trailing edge was kept ice free.

National Advisory Committee for Aeronautics tests have indicated that a pusher propeller, driven by an extension shaft from an engine housed in the wing is a more efficient combination than any radial engine driven tractor or pusher airscrew combination tested. There may be additional advantages, both aerodynamic and to the engine, in the discharge of exhaust gases in the manner suggested.

Experience with stainless steel silencers for aircraft engines indicates that the use of stainless steel overcomes corrosion troubles. Stainless steel is now being introduced for aircraft construction.

The driving of an airscrew by means of an extension shaft has been proved feasible by the long service of such drives in the Junker G-38. More recently, military aircraft have been built in which this form of drive is employed.[26]

In addition to other advantages, propulsion of aircraft by means of airscrews, driven through extension shafts from engines housed in the wings, is a convenient arrangement for the prevention of ice by utilization of waste heat. For the method suggested, using a slotted nose section, the connections would be very direct. It makes possible the utilization of heated air from air-cooled engines, or from ducted radiators and condensers in liquid or steam-cooled engines, alone or in combination with air heated by the exhaust.

[26]The Westland F7-30 and Koolhoven FK-55.

Instrument Equipment

The success of the transatlantic air service will depend very largely upon the piloting and navigation, and the aircraft must therefore be provided with the best and most comprehensive of instrument equipment.

For a long range service of this kind, an automatic pilot is essential. This instrument automatically maintains the aircraft on a pre-set course and in a given trim, thereby increasing the accuracy of course keeping and of control, improving control in bad weather or conditions of low visibility, reducing the risk of loss of control under such conditions and reducing the strain on and fatigue of the pilot.

The automatic pilot includes two indicating instruments which serve also with manual control, namely the gyro horizon and the directional gyro. It is desirable, however, to provide duplicates of these as a precautionary measure.

In addition to the instruments included in the automatic pilot, essential instruments for blind flying, which may be used in different combinations, include the gyro turn indicator, ball or pendulum type cross level or side slip indicator, rate of climb indicator, or fore and aft level, airspeed indicator and sensitive altimeter.

For navigation, in addition to the foregoing, there should be provided at least two magnetic compasses, one of which may be arranged to control the directional gyro, drift and ground speed indicator, course and distance calculators, chronometer, astronomical instruments such as bubble sextant, radio compass and other radio direction finding equipment to which reference has already been made.

The need for the most complete engine instrument equipment for this service, where proper functioning of the power plant is so important, need not be emphasized. Fuel-air indicators and fuel flow meters should be included.

For catapulting, provision of a fore and aft accelerometer is desirable.

For the detection of icing conditions and ice, a distant reading thermometer and suitable lights are necessary.

Summary

To summarize the foregoing, the suggested aircraft for the initial transatlantic service should be one designed for the carriage of mail and express, having a pay load capacity of 1,500-2,000 lb., a cruising speed of 180 m.p.h., a range of 2,400 miles against a headwind of 30 m.p.h. and fitted for catapult launching at a speed of 100 m.p.h. The type, either flying boat, amphibian or wheeled aeroplane, will be determined by the terminal conditions. The aircraft should be a monoplane and, if a boat or amphibian, a high wing monoplane. If a wheeled aeroplane, it should be fitted with a retractable undercarriage and provided with ample flotation in the form of water-tight compartments and wings. Provision should be made for landing on snow or ice.

The wing loading should be high—40-50 lb. per sq. ft.—the aerodynamic design clean and the structure weight carefully controlled to permit a weight ratio of not less than 2:1. The aircraft should be multi-engined, with, initially, air-cooled gasoline engines, moderately supercharged to 5,000-6,000 ft., equipped with automatic controls, and fitted with variable pitch or constant speed airscrews. Early consideration should be given to liquid cooled and sleeve valve engines and especially to compression ignition engines.

The aircraft should be fitted with lift-increasing devices to reduce the landing speed after a ten-hour flight to 60-65 m.p.h., with wheelbrakes and with dump valves in the fuel tanks.

Full provision should be made for the detection and prevention of icing.

The instrument equipment should include automatic pilot and complete blind flying, navigation and engine instruments.

Conclusion

Determined efforts are about to be made to establish a commercial air service by aeroplane across the North Atlantic and thereby surmount one of the last of the great barriers to the linking of the continents by air transport.

In this paper, an attempt has been made to review the different aspects of the problem, the various considerations involved and to outline the organization, in a general way, of a commercial transatlantic air service.

The successful establishment of a transatlantic air service between London and Montreal will mark another achievement in the progress of transportation and one in which Canada will continue her close association of the past with new developments in transportation.

Acknowledgments

The author desires to express his thanks for their assistance in the preparation of this paper to Mr. J. A. Wilson for information pertaining to the trans-Canada airway, to Mr. G. Herring for information regarding postal rates, etc., and for checking the section dealing with Canadian ship-shore services, to Dr. J. T. Henderson for his checking of the section on Radio Service, to Mr. S. J. Murphy for his suggestions in connection with the section on Instruments, to Mr. K. F. Tupper for his preparation of Table IV and his checking of certain sections of the paper, and to those gentlemen and organizations mentioned in the paper who so kindly furnished information.

APPENDIX I

North Atlantic Air Crossings*

(A) Non-Stop

No.	Date	Pilot	Route	Aircraft	Time	Miles
	1919					
1	June 14	Alcock and Brown	St. Johns-Clifden	Vickers Vimy	16-12-00	1,890
2	July 2- 6	Scott and 28	East Fortune-Garden City, N.Y.	HMA-R-34	108-12-00	3,270
3	July 9-12	Scott and 28	Garden City-Pulham	HMA-R-34	75-00-00	
	1924					
4	Oct. 12-15	Eckener and 31	Friedrichshafen, Basle, Bordeaux, Azores, Grand Banks, Cape Race, Long Island, Lakehurst, N.J.	ZR-3 (Los Angeles)	81-17-00	4,010
	1927					
5	May 20-21	Lindbergh	New York-Paris	Ryan	33-29-30	3,620
6	June 4- 5	Chamberlin and Levine	New York-Eisleben, Germany	Bellanca	42-00-00	3,930
7	June 29-July 1	Byrd and 3	New York-Var-sur-Mer	Fokker	43-30-00	3,490
8	Aug. 27-28	Brock and Schlee	Harbour Grace-Croydon	Stinson	23-21-00	2,350
	1928					
9	Apr. 12-13	Huenefeld and 2	Baldonnel (Dublin)-Greenly Island (Lab.)	Junker L-33	37-00-00	2,070
10	June 17-18	Stultz and 2	Trepassy Bay-Burry Port, Eng.	Fokker VII	20-40-00	4,449
11	Oct. 11-15	Eckener, 38 and 19 pass	Friedrichshafen, Gibraltar, Madeira, Azores, Bermuda, Virginia coast, Lakehurst	Graf Zeppelin	111 38-00	6,160
12	Oct. 29-Nov. 1	Eckener, 39 and 20 pass.	Lakehurst-Friedrichshafen (slightly south of great circle)	Graf Zeppelin	75-33-00	
	1929					
13	June 13-14	Assolant and 3	Old Orchard, Me.-Commillas, Spain	Bernard	29-52-00	3,000
14	July 8	Williams and Yancey	Old Orchard, Me.-Santander, Spain	Bellanca	31-30-00	
15	Aug. 1- 4	Eckener, 41 and 19 pass.	Friedrichshafen-Lakehurst	Graf Zeppelin	93-23-00	
16	Aug. 8-10	Eckener and ?	Lakehurst-Friedrichshafen	Graf Zeppelin	55-00-00	
17	Sept. 1-14	Lehmann, 41 and 17 pass.	Lakehurst-Friedrichshafen (Round world cruise)	Graf Zeppelin	66-00-00	
	1930					
18	June 23-24	Kingsford Smith and 3	Port Marnock, Ireland-Harbour Grace	Fokker VII	30-28-00	
19	July 29-Aug. 1	Booth and 43	Cardington-Montreal	HMA-R-100	78-52-00	
20	Aug. 14-16	Booth and 43	Montreal-Cardington	HMA-R-100	56-12-00	
21	Sept. 1- 2	Costes and Bellonte	Paris-New York	Brequet	37-17-00	3,610
22	Oct. 9-10	Boyd and Conner	Harbour Grace-Tresco, Scilly Islands	Bellanca	23-44-00	2,260
	1931					
23	June 23-24	Post and Gatty	Harbour Grace-Chester, Eng.	Lockheed Vega		
24	June 24-25	Hoiriis and Hillig	Harbour Grace-Krefeld, Germany	Bellanca	32-00-00	
25	July 15-16	Endres and Magyar	Harbour Grace-Bickse (Budapest)	Lockheed Sirius	26-12-00	
26	July 28-29	Boardman and Polando	New York-Istanbul, Turkey	Bellanca		
27	July 28-29	Herndon and Pangborn	New York-Moylgrove, Wales	Bellanca	32-00-00	
	1932					
28	May 21	Earhart	Harbour Grace-Culmore, Ireland	Lockheed Vega	15-40-00	2,026
29	July 5- 6	Mattern and Griffin	Harbour Grace-Berlin	Lockheed	18-40-00	
30	Aug. 21	Mollison	Portmarnock, I.F.S.-Pennfield Ridge, N.B.	Puss Moth	30-12-00	
	1933					
31	June 3- 5	Mattern	New York-Moscow	Lockheed	32-00-00	4,920
32	July 15-16	Post	Brooklyn, N.Y.-Berlin	Lockheed	25-48-00	3,942
33	July 15-17	Darius and Girenas	Brooklyn, N.Y.-Soldin, Germany	Bellanca	crashed	
34	July 22-23	Capt. and Mrs. Mollison	Pendine Sands, Wales-Stratford, Conn.	DeH Dragon		
35	Aug. 5- 7	Codos and Rossi	Brooklyn-Rayak, Syria	Bleriot		5,656
36	Nov. 1-	Eckener, crew and 22 pass.	Chicago, Akron, Seville, Friedrichshafen	Graf Zeppelin		
	1934					
37	May 14-15	Pond and Sabelli	Brooklyn-Lahinch, I.F.S.	Bellanca	32-00-00 ?	
38	May 28	Codos and Rossi	Paris-Brooklyn	Bleriot	38-30-00	3,280
39	July 1	Adamowicz Bros.	Harbour Grace-Flens de Lorne, France	Bellanca		
40	Aug. 9	Ayling and Reid	Wasaga Beach, Ont.-Middlesex, Eng.	DeH Dragon	30-51-00	3,500
	1935					
41	Sept. 21-22	Waitkus	Brooklyn-Ballenrobe, I.F.S.	Lockheed Vega	23-15-00	
	1936					
42	May 6	Eckener, 54 and 50 pass.	Friedrichshafen-Lakehurst (northern route)	LZ 129 Hindenburg	61-40-00	4,407
43	May 11	Eckener, 54 and 53 pass.	Lakehurst-Friedrichshafen (over north of England)	LZ 129 Hindenburg	49-45-00	4,089
44	May 16	Crew 54, pass. 41	? -Lakehurst	LZ 129 Hindenburg	78-29-00	4,453
45	May 20	Crew 54, pass. 57	Lakehurst- ?	LZ 129 Hindenburg	48-08-00	4,044
46	June 19	Eckener, 53, pass. 42	Frankfurt-am-Main-Lakehurst	LZ 129 Hindenburg	61-20-00	4,194
47	June 23	Crew 54, pass. 56	Lakehurst-Frankfurt (crossed England)	LZ 129 Hindenburg	61-10-00	3,980
48	June 30	Crew 55, pass. 21	Frankfurt-Lakehurst (via St. Lawrence valley)	LZ 129 Hindenburg	52-48-00	4,166
49	July 3	Crew 55, pass. 54	Lakehurst-Frankfurt	LZ 129 Hindenburg	45-39-00	3,917
50	July 10	Crew 53, pass. 50	Frankfurt-Lakehurst (via Azores)	LZ 129 Hindenburg	63-37-00	4,179
51	July 14	Crew 53, pass. 56	Lakehurst-Frankfurt	LZ 129 Hindenburg	60-58-00	4,451
52	Aug 5	Lehman, 56, pass. 50	Frankfurt-Lakehurst	Lz 129 Hindenburg	75-26-00	4,966
53	Aug 9	Lehman, 56, pass. 54	Lakehurst-Frankfurt	LZ 129 Hindenburg	42-52-00	4,127
54	Aug 15	Crew 58, pass. 58	Frankfurt-Lakehurst	LZ 129 Hindenburg	71-00-00	4,694
55	Aug 19	Crew 58, pass. 58	Lakehurst-Frankfurt	LZ 129 Hindenburg	43-48-00	4,012
56	Sept. 17	Crew 59, pass. 72	Frankfurt-Lakehurst	LZ 129 Hindenburg	62-55-00	4,107
57	Sept. 21	Crew 59, pass. 59	Lakehurst-Frankfurt	LZ 129 Hindenburg	55-36-00	4,121
58	Sept. 26	Crew 57, pass. 44	Frankfurt-Lakehurst	LZ 129 Hindenburg	63-12-00	4,236
59	Sept. 30	Crew 57, pass. 41	Lakehurst-Frankfurt	LZ 129 Hindenburg	58-25-00	4,078
60	Oct. 5	Crew 60, pass. 53	Frankfurt-Lakehurst	LZ 129 Hindenburg	55-25-00	4,112
61	Oct. 3	Crew 60, pass. 49	Lakehurst-Frankfurt (crossed England)	LZ 129 Hindenburg	52-30-00	?
62	Sept. 2-3	Merrill and Richman	Brooklyn-Llandilo, S. Wales	Vultee V-1a	18-38-00	3,300
63	Sept. 4	Mrs. Markham	Abingdon-Baleine Cove, N.S.	Percival Vega Gull	25-10-00	2,700
64	Sept. 14	Merrill and Richman	Southport-Musgrave Harbour, Nfld.	Vultee	15-17-00	2,300
65	Oct. 30	Mollison	Harbour Grace-Croydon	Bellanca	13-17-10	2,100

*Up to December 31st, 1936. (While the list is thought to be reasonably complete and accurate, there may be omissions and errors.)
Particulars regarding the Hindenburg kindly supplied by F. W. von Meister, Special U.S. Representative of Deutsche Zeppelin Reederei and Luftschiffbau Zeppelin.

APPENDIX I—(Continued)

(B) BY STAGES

No.	Date	Pilot	Route	Aircraft	Time	Miles
	1919					
1	May 16-31	Read and 5	Trepassy Bay-Azores-Lisbon	NC-4		2,437
	1924					
2	July 17-Sept. 6	Smith, Arnold, Nelson and Harding	Brough - Kirkwall - Hornafjord - Reykjavik - Frederiksdal - Ivigtut - Ice Tickle Bay (Lab.)	Douglas	39-23-00	2,850
3	July 17-Sept. 6		(Aug. 31)—Hawkes Bay, Nfld., Pictou, N.S., Casco Bay, Boston. (Round world flight)	Douglas		
	1927					
4	May 23-June 13	Pinedo and 2	Trepassy-160 miles off Azores-St. Michaels-Lisbon	Savoia		
	1930					
5	Aug. 19-26	Gronau and 3	Warnemünde - Faroes - Reykjavik - Ivigtut - Cartwright - Queensport - Halifax-New York	Wal	47-00-00	
	1931					
6	Aug. 7-17	Gronau and 3	List—Faroe Islands - Reykjavik - Scoresby Sound - Sukkertoppen-Godthaab-Port Harrison-Long Lac-Chicago	Wal		
	1932					
7	May 21-22	Christiansen and 14	Holyrood-Conception Bay-Azores-Vigo-Calshot	DO-X	28-55 00	2,310
8	July 22-27	Gronau and 3	List-Seydisfjord-Reykjavik-Ivigtut-Cartwright-Montreal	Wal		
	1933					
9	July 1-14	Balbo and 96	Orbitello-Amsterdam-Londonderry-Reykjavik-Cartwright-Shediac, N.B.-Montreal-Chicago	24 Savoia S 55 X		
10	July 22-Aug 26	Colonel and Mrs. Lindbergh	Long Island-Cartwright-Hopedale-Godthaab-Angmagsalik-Reykjavik-Ivaerad (Faroe)-Lerwick (Shetland)-Copenhagen	Sirius		
11	July 25-Aug. 14	Balbo and 96	Brooklyn-Shediac-Shoal Harbour-Azores-Lisbon-Ostra (Rome)	24 Savoia S 55 X	48-47-00	6,065
	1934					
12	July 20-Aug. 30	Grierson	London - Londonderry - Reykjavik - Angmagsalik - Godthaab - Lake Harbour-Povungnituk-East Main-Ottawa	Fox Moth		4,000
	1936					
13	Sept. 5-10	Blankenburg and 3	Lisbon-Punta Delgada-Azores (Schwabenland)-Port Washington, N.Y.	DO18 Zephyr	22-14-00	2,390
14	Sept. 5-12	Engel and 3	Lisbon-Punta Delgada-Azores (Schwabenland)-Bermuda-Port Washington, N.Y.	DO18 Aeolus	24-19-00	2,833
15	Sept. 22-23	Engel and 3	Port Washington (Schwabenland)-Azores	Aeolus	17-50-00	2,400
16	Sept. 24	Blankenburg and 3	Port Washington-Bermuda (Schwabenland)-Azores	Zephyr	?	?
17	Oct. 7	Blankenburg and 3	Azores (Schwabenland)-Port Washington, N.Y.	Zephyr	18-20-00	
18	?	Engel and 3	Azores (Schwabenland)-Port Washington, N.Y.	Aeolus	?	
19	Oct. 17	Engel and 3	Sydney, N.S. (Schwabenland)-Azores	Aeolus	?	1,800?
20	Oct. 18	Blankenburg and 3	Sydney, N.S. (Schwabenland)-Azores	Zephyr	?	1,800?

*Up to December 31st, 1936. (While the list is thought to be reasonably complete and accurate, there may be omissions and errors.)

APPENDIX II

CANADIAN SHIP-SHORE AIR MAIL SERVICES

1. *Record of Montreal-Rimouski Summer Service**

Year	Single trips Scheduled	Single trips Completed	Mail carried (pounds)
1927		10	2,469
1928		94	62,834
1929	124	114	68,672
1930	92	72	54,044
1931	97	87	54,801
1932	83	69	38,987
1933	66	54	33,253
1934	59	50	31,546
1935	63	60	39,390
1936	63	54	42,676

2. *Record of Montreal-Moncton Winter Service**

Year	Route	Single trips Scheduled	Single trips Completed	Mail carried (pounds)
1929	Montreal-Saint John	66	56	4,279
1930	Montreal-Moncton	504	358	7,256
1931	Montreal-Moncton	206	169	2,775

3. *Schedule of Red Bay-Ottawa Service, 1932*

London—leave 2.00 p.m.—by aeroplane to Cherbourg.
Cherbourg—leave 6.30 p.m.—by *Empress of Britain.*
Strait of Belle Isle—2.30 a.m., third day out—transferred by naval tender.
Red Bay-Havre St. Pierre—by seaplane, 386 miles, 4 hours.
Havre St. Pierre-Rimouski—by flying boat, 290 miles, 3½ hours.
Rimouski-St. Hubert (Montreal)—by aeroplane, 314 miles, 3½ hours, arrive 4.00 p.m.—mail sorted.
Montreal-Ottawa—by aeroplane, 110 miles, 1 hour, arrive 5.30 p.m.
1,100 miles flown in 12 hours' flying time and 15 hours' elapsed time.

*Figures kindly furnished and checked by Mr. G. Herring, Chief Superintendent, Air and Land Mail Services.

APPENDIX III

SHIP-SHORE CATAPULT EQUIPMENT

(A) *Ile de France Installation.*

Catapult—compressed air operated
overall length 111 ft. 7 in.
weight 60 tons
launching capacity 4 tons at 112 m.p.h.

Aircraft— Liore and Olivier amphibian
weight 7,275 lb.
speed 105 m.p.h.
range 7 hours at 90 m.p.h.

later— CAMS—37 amphibian

(B) *Bremen and Europa Installations.*

Catapult—Heinkel K-2
compressed air operated—air pressure 28-78 atmospheres, depending on the wind speed
accelerating distance 65.6 ft.
braking distance 9.84 ft.
weight including catapult, circular rail and pivot and excluding understructure and compressor installation—260 tons
launching capacity 4 tons at 62.2 m.p.h.

Aircraft—Bremen—Heinkel He-12—low wing seaplane
weight empty 3,454 lb., loaded 5,100 lb
later Junker Ju 46 with extra tanks
range 11 hours at 112 m.p.h. cruising speed
Europa—Heinkel He-58.

APPENDIX IV

Record of N.D.L. Bremen-Europa Ship-Shore Service

Westbound*—To New York

Year	Flights	Flying time Min.	Flying time Max.	Flying time Aver.	Distance Min.	Distance Max.	Distance Aver.	Bags and parcels	Weight pounds
1929	3						106		
1930	11						263		
1931	14	00:44	17:00	6:12	60	1,340	513	4	
1932	18	00:20	11:25	5:54	20	830	478	4	36.3
1933	17	00:45	9:35	6:26	70	735	554	7	44.1
1934	18	3:13	10:20	7:32	248	856	694	6	60.3
1935	17	2:32	11:24	8:17	224	901	693	7	120.5

Eastbound—To Southampton and Bremershaven

Year	Flights	Distance Aver.
1929	4	342
1930	11	923
1931	14	1,026
1932	17	1,094
1933	17	1,108
1934	18	1,310
1935	?	?

*Information kindly furnished by the Hamburg-America Line and North German Lloyd.

APPENDIX V

Transatlantic Traffic

Europe-North America

Passenger

	Westbound	Eastbound
Canadian Ports (1)		
Calendar year 1936		
Quebec	12,064	8,605
Halifax	5,773	4,150
Montreal	41,295	45,781
Total	59,132	58,536
United States Ports (2)		
Calendar year 1935		
Northern—First	21,848	21,842
Cabin	21,483	20,659
Total	157,356	164,851
Southern—First	16,910	16,136
Cabin	9,551	8,563
Total	92,241	73,205
Total— First	38,758	37,978
Cabin	31,034	29,222
Total	249,597	238,055
von Hindenburg 1936 (3)	481	537

Mail

		Pounds
Canadian Ports (4)		
Calendar year 1936		
First class		759,000
Prints, etc.		2,394,000
Parcel		523,000
Total		3,676,000
United States Ports (5)		
Year ending June 30th, 1936		
U.S. Letters		2,517,605
Prints		13,537,543
Parcels		10,800,377
Foreign Letters		273,088
Prints		889,234
Parcels		14,118
Total		28,031,765
via von Hindenburg (1936)	4,892 (260,379 pieces)	4,556 (195,964 pieces)

Freight (cargo tons of 2,240 lb.)

	Westbound	Eastbound
Canadian Ports (6)		
Year ending March 31st, 1936	3,453,000	7,108,374
United States Ports (2)		
Calendar year 1935		
Ports in North Atlantic District From and to		
United Kingdom	803,385	1,115,904
North Atlantic and Baltic Europe	1,479,615	415,659
Havre-Hamburg Range	1,244,164	1,386,361
South Atlantic Europe	473,355	202,203
West Mediterranean	380,967	786,923

(1) Information kindly furnished by National Harbours Board, Dept. of Transport, Canada.

(2) Information kindly furnished by United States Maritime Commission.

(3) Information kindly furnished by Mr. F. W. von Meister.

(4) Information kindly furnished by Post Office Department, Ottawa.

(5) Information kindly furnished by United States Post Office Department.

(6) Information kindly furnished by Dominion Bureau of Statistics.

APPENDIX VI

Fog—North American Coast

Table I—Normal Percentage of Days with Fog at Points in Newfoundland and on the Gulf of St. Lawrence

Information supplied by the Director, Meteorological Service of Canada.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Aver.
St. Johns, Newfoundland	4	5	6	17	17	9	15	12	9	7	9	3	9
Belle Isle	7	5	13	29	39	42	55	41	27	24	15	4	25
Yarmouth	4	4	5	9	11	16	30	26	15	9	2	4	11
Saint John, N.B.	7	10	7	11	15	27	34	34	19	14	8	7	16
Bird Rocks	6	6	10	18	27	29	28	12	11	11	9	5	14
Charlottetown	1	1	3	3	1	−1	−1	0	1	1	2	1	1
Father Point	0	0	1	3	3	6	9	6	4	4	0	0	3
Quebec	3	3	3	3	3	1	0	3	6	5	4	3	3

Table II (*a*)—Percentage of Days with Fog at Lighthouses on the Newfoundland Coast

From "Fog at Sea," W. E. Hurd, U.S. Weather Bureau

Pilot Chart of Upper Air—North Atlantic Ocean, December 1936

(Data supplied by Inspector of Lighthouses, Newfoundland)

Lighthouse	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec	Aver.
North-East Coast													
Notre Dame Bay—													
Gull Is. (1900-11 inc.)	3	10	10	16	21	27	23	16	10	10	14	8	14
Nippers Harbour (1902-11 inc.)	1	2	3	7	11	9	8	6	3	9	11	5	6
Long Is. (1904-11 inc.)	1	4	2	5	10	10	4	4	6	4	8	7	5
Long Point (1900-11 inc.)	2	8	9	11	15	15	11	5	6	4	5	8	8
East Coast—Central Portion													
Catalina Harbour—													
Green Is. (1900-06, 08-11 inc.)	6	6	7	11	11	14	22	11	8	7	12	5	10
East Coast—Southern Portion													
Conception Bay—													
Cape St. Francis (1900-11 inc.)	6	12	10	17	19	19	19	11	9	10	13	10	13
Near Cape Spear—													
St. Johns' Harbour (1900-7, 9-11 inc.)	19	14	14	27	27	34	34	24	17	20	18	14	22
South Coast, near extreme Eastern Portion													
Trepassey Bay—													
Powell's Head (1903-07 inc.)	6	4	4	15	13	16	32	12	1	6	8	6	10
South Coast, near extreme Western Portion													
Channel Head (1900-07 inc.)	5	3	4	15	13	16	31	17	11	8	2	4	11
West Coast													
Bay St. George—													
Sandy Point (1900-8, 10-11)	0	0	0	1	1	2	2	2	1	1	0	0	1
Bay of Islands—													
Frenchman Head (1902-8, 10)	0	0	1	5	14	11	11	6	5	5	3	1	5
Bonne Bay—													
Lobster Cove Head (1900-10)	0	0	1	3	5	7	14	6	2	3	1	1	4
Keppel Harbour—													
Keppel Island (1901-10)	0	0	0	1	4	5	13	6	2	2	1	1	3

Table II (*b*)—Percentage of Days with Fog at North American Stations

12-16 years' record

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Aver.
Belle Isle	13	18	19	18	30	44	63	49	38	32	24	7	30
Father Point	½	½	2	3	4	9	8	8	6	4	½	½	4
St. Johns	11	10	12	14	20	18	12	10	8	12	11	8	12
Sydney	5	5	6	11	10	7	6	5	5	5	9	7	7
Halifax	6	5	6	9	14	11	15	9	6	5	5	3	8
Quebec	2	1½	1	3	½	½	1	1	3	5	4	2	2
Montreal	3	2	2	2	½	0	0	0	2	5	3	2	2
New York						3						10	
Norfolk						3						6	

APPENDIX VII

Depot Ships of the Deutsche Luft Hansa

In organizing its air mail service to South America, the Deutsche Luft Hansa adopted depot ships as the most satisfactory solution of the problem of operating the service across the South Atlantic under the conditions. The conditions confronting the D.L.H. included lack of aircraft capable of making the crossing non-stop with sufficient payload, lack of colonies and hence sites for bases and lack of airports with adequate facilities to permit the use of large heavily loaded landplanes.

Possessing in the Dornier Wal an efficient and seaworthy, long range flying boat, capable, almost fully loaded, of alighting and remaining afloat for days in South Atlantic weather and of taking off unaided from sheltered water, the use of depot ships enabled the D.L.H. to start the service without waiting for larger aircraft able to make the 1,890-mile ocean flight from Bathurst, Gambia to Natal, Brazil, non-stop.

Following successful trial flights to and from the depot ship *Westfalen*, stationed in mid-ocean, in November 1933, a regular fortnightly service (each way) was commenced February 4th, 1934, and a weekly service in September 1934. The service has been operated, with a high degree of regularity since that time, largely with Dornier Wals improved in 1934, driven by two-geared BMW-VIu motors and having a range of 1,680 miles, cruising at 120 m.p.h., the all-up weight being 22,000 lb. The first night flight was made October 23rd, 1934.*

In April 1934, the 5,500 miles from Pernambuco, Brazil, to Stuttgart were flown in two days, twenty-three hours, forty-five minutes. The average overall time from Stuttgart to Rio is fifty-five to fifty hours.

The mail load, each way, was originally 150 to 175 lb. (about 20,000 letters) and is now 450 to 500 lb., the capacity being 880 lb.

The German air mail letter rate is 1.50 and 1.25 marks for 5 grammes (1.6 oz.) to Buenos Aires and Rio de Janeiro respectively.

Up to the end of 1936, over 200 ocean flights had been made and more than 10,000,000 letters carried, with the loss of one aircraft only.

The D.L.H. now has three depot ships in service, the *Westfalen*, a converted Norddeutscher Lloyd cargo ship, the *Schwabenland*, formerly a cargo and passenger ship of the Dampfschiffahrts Gesselschaft Hansa and the *Ostmark*, a specially built motor ship placed in service in 1936. Particulars of these ships are given in the accompanying table.

The depot ships are fitted with the following equipment: a compressed air operated catapult for launching the flying boats; a rotating and folding electric crane for lifting the flying boats on deck or on the catapult; a trailing apron or "stausegel" to facilitate hoisting the aircraft aboard in rough weather; complete radio and meteorological equipment; accommodation for aircraft on deck to permit servicing and repairs.

The apron, invented by Herr Hein, is of sailcloth some 100 ft. long, with bamboo spreaders and drag pockets on the under side. It trails from a roller at the stern of the ship and, when not in use, is rolled up. When the aircraft alights, the ship reduces way, the apron submerges and the aircraft taxies on it. The ship then speeds up, the canvas becomes taut and raises the aircraft almost entirely out of the water. A secure connection between ship and aircraft is thus provided so that, even in a heavy sea, the aircraft can be lifted inboard by the crane without risk.

The *Westfalen* and *Schwabenland* each have two short wave transmitters (800 watts for distant ground station and 60 watts for aircraft), one medium wave transmitter (key and voice, 300-3,000 m.), duplicate receivers and loop aerial for direction finding.

The aircraft are equipped with 20 watt medium and short wave transmitters and receivers and loop aerial. The normal range of the loop aerial is 600 nautical miles and occasionally up to 900 miles.

The *Ostmark* is equipped with four standard transmitters and six receivers for long and short waves, including an emergency spark transmitter and a radiogoniometer.

The ships are also equipped as meteorological and oceanographic stations, staffed by the Deutsche Seewarte. Weather reports are received from each other, from ships at sea, and from land stations, particularly upper air pilot balloon observations from West African stations. Balloon observations are also made from the ships. Weather maps and forecasts are prepared in each ship for each flight.

Originally, the D.L.H. employed the depot ship primarily as a refueling station. The old 7-ton Wals were unable to fly non-stop across the South Atlantic. The flying boat flew to the depot ship, stationed in mid-ocean, and alighted on the sea. The mail was transferred to a second aircraft, already prepared on the catapult, which was then launched and continued the crossing while the first was hoisted aboard, refueled and made ready to continue the next crossing. Alternatively, on reaching the depot ship, the aircraft was hoisted aboard, refueled and launched to complete the crossing.

With the improved 10-ton Wals, having range sufficient for the whole flight from Africa to Brazil, there was no need for mid-ocean refueling and the depot ships have functioned as launching stations. As such, stationed in sheltered water, and with improved crane arrangements, the need for the trailing apron has largely disappeared. With two depot ships, one is stationed at Bathurst, the second at Fernando de Noronha. At Bathurst, the mail is placed on the aircraft on the ship; the latter leaves port and the aircraft is launched. On reaching the second ship, if enough fuel is left, the aircraft continues to Natal, otherwise it alights and is refueled. From Natal, the aircraft flies to the depot ship, is taken aboard, the ship puts to sea and some hours later the aircraft is catapulted toward Bathurst.

The Deutsche Luft Hansa apparently contemplates initiating in 1937 a North Atlantic service via the Azores and Bermuda, using the same technique which has proved so successful in the South Atlantic. The *Schwabenland* and a sister ship, now building, will be used for launching

The oversea flight being longer, new aircraft have been built for the North Atlantic. These are the Dornier DO18 flying boats, powered by tandem Junker Jumo 500/560 Diesel engines and designed for the carriage of mail and express over long distances after catapulting, and the Ha139 twin float monoplanes for catapulting, built by the Hamburger Flugzeugbau, weighing 11½ tons, with four Jumo motors and having a top speed of 186 m.p.h. and a range of 3,100 miles.

During September and October 1936, the *Schwabenland*, the largest of the three ships, was used in trial flights across the North Atlantic by two DO18 flying boats, to study flying conditions, equipment, navigation and landing facilities. In these trials, the depot ship functioned as a launching station. Two flights each way were made. First launched westward at the Azores, the two aircraft flew to New York, one non-stop (2,390 miles) and the other via Bermuda (2,063 miles) where it was again catapulted. The *Schwabenland*, having followed to New York, the aircraft were catapulted for the eastward flight via Bermuda to the Azores. The second westward crossing was made non-stop to New York. The aircraft then flew to Sydney, N.S., were launched from the ship and flew to the Azores.

The flights were reported successful. With the exception of a leaking radiator, during one of the first westward flights, there was no trouble and no replacements were necessary in the aircraft or motors and the flights were made, without waiting, in such weather as occurred.

As a refueling base, and for launching aircraft, the catapult equipped depot ship possesses the advantages of mobility and lower cost. If the aircraft is forced down at sea within reasonable distance, the ship can proceed to it and, in a moderate sea, using the trailing apron, the aircraft can be taken aboard. As a launching device, the mobility of the depot ship permits the base to be shifted at will. The cost of the ship is relatively low and the Diesel engined depot ship is economical to operate, due to the absence of standby losses when not under way, the readiness for immediate service and to the economy of and small space occupied by the engines.

Deutsche Luft Hansa Depot Ships

Ship	*Westfalen*	*Schwabenland*	*Ostmark*
Fitted out or built	1932	1934	1936
Type	steam	twin ? Diesel	twin Diesel
Gross registered tonnage	5,124	8,188	2,000
Power—hp	2,750	3,600	1,800-2,000
Speed—knots	11.5	12	13½-15
Length—ft	410-0	460-0	245-0
Beam—ft	52-6		37-6
Draught—ft	28-0		
Crew	40		
Gasoline tankage—gals	8,800	19,800	
Catapult			
Type	Heinkel K-6	Heinkel	Heinkel K-9
Location	bow	stern	bow
Maximum capacity—			
Gross weight—lb	30,860	30,800	33,000
Take-off speed—m.p.h	93	93	93
Maximum acceleration	3.5 *g*	3.5 *g*	
Mean acceleration	2.8 *g*	2.8 *g*	
Length of accel. run—ft	103-9	103-9	103-9
Length of braked run—ft	16-5	18-0	18-0
Total length—ft	138-0	136-0	136-0
Width	6-6	7-3	
Weight of carriage—lb			3,960
Stroke of piston	18-8		
Maximum pressure—atmos	150	160	160
Total weight—lb	128,000	205,000	
Crane—Electric			
Type	rotating	rotating and folding	rotating
Maximum load—lb	33,000	33,000	33,000
Aircraft Accommodation			
Number		3	1

*For catapulting on moonless nights, a motor drive was fitted to the artificial horizon.

APPENDIX VIII

Armstrong Seadromes

In the floating aerodrome as developed by Edward R. Armstrong for use as a refueling station on Atlantic air routes, the flight deck is 1,500 ft. long and 300 ft. wide amidships, and 150 ft. wide at the ends. The deck is supported some 100 ft. above sea level on 32 buoyancy units, in the form of vertical streamlined telescoping columns, the upper portions of which constitute buoyancy chambers and the lower, ballast chambers. When the seadrome is in place the cylinders are extended, the ballast sections sinking to a depth of about 200 ft. The buoyancy units are of streamline section to reduce the resistance to the passage of waves, and are so designed that the centres of buoyancy and gravity are well below the water surface. As a result, it is claimed that tank tests have shown that the seadrome is unaffected by wave motion and has no tendency to roll or pitch. It is said that theory indicates and experience in submarines confirms that wave action is hardly perceptible at a depth of 200 ft.

A second deck, below the flying platform and reached by elevator, carries hangars, workshop, radio and meteorological stations and accommodation for crew and passengers.

The decks and buoyancy units are interconnected by lattice beams to form a rigid structural unit weighing some 28,000 tons. The displacement with full ballast tanks will be about 67,000 tons.

The difficulty of mooring the seadrome under Atlantic conditions is believed to have been overcome. The conditions designed for are: depths of 3-4 miles, 70 mile wind, and 1½ knot current, the latter imposing a cable tension of some 200,000 lb.

The mushroom shaped 1,650 ton anchor will be floated to position, buoyancy chambers will then be flooded and the rate of descent of the anchor checked by canvas drogues.

The anchor will be connected to a triangular buoy of the same type of construction as the seadrome, by means of two suspension bridge type steel cables connected through chains to the anchor.

The triangular anchor buoy will carry beacon light and radio equipment.

The seadrome is in turn connected to the buoy. To provide a further margin under extreme conditions and also for manoeuvring, four of the buoyancy units of the seadrome are fitted with electric motor driven propellers capable of developing a total thrust of 100,000 lb.

The cost of each seadrome unit is estimated to be between six and seven million dollars.

The seadrome project contemplates the stationing of seadromes at approximately 500-mile intervals between Europe and America, in one case along the 38th parallel of latitude to secure better weather conditions, or, as proposed by M. Bleriot, near the latitude of New York. The latter suggested that if initially all seadromes were not constructed, intermediate floating islands equipped as meteorological and radio stations and beacons should be provided, anchored in the same manner as the seadromes, and hence readily replaced by the latter when constructed. A somewhat similar suggestion has been made in connection with the Pacific route; that small structures, resembling the anchorage buoy of the seadromes, equipped as radio and meteorological stations, and with lifeboats and motor patrol boat to send supplies to aircraft forced down, should be provided at a cost of about $200,000 each.

The economics of the seadrome project, as outlined by M. Louis Bleriot, are:

Capital cost—	
4 seadromes at 110,000,000 fr. each say	500,000,000 fr.
Yearly revenue—	
Postal 2/7 of receipts from carriage of 500 tonnes of letters and 800 tonnes of papers and parcels to yield	90,000,000 fr.
Passenger 1/5 of receipts from fares of 80,000 passengers at 5,250 fr. each	60,000,000 fr.
Other sale of gasoline and oil, rental of hangars and stores, hotels, etc.	12,000,000 fr.
Total say	170,000,000 fr.
Operating charges—	
Maintenance, salaries, insurance	33,000,000 fr.
Balance say	140,000,000 fr.

Technically the construction, anchorage and seaworthiness of the seadrome appears practicable and it is reported to have received the approval of the U.S. Navy Department and of marine engineers.

From an aeronautical standpoint experience with aircraft carriers would indicate the plan to be feasible, although the deck area may be inadequate for modern, large, high speed, commercial aircraft with high wing loading, and landing in fog would be hazardous.

A serious obstacle to the project is the uncertainty as to the territorial status of the seadrome. Is it a ship or territory—national or international? What is its status in war? Virtually it appears to be an island, well stocked with fuel and other supplies, but an island capable of being moved and hence a valuable prize.

The lower cost per pound rendered possible by the smaller fuel load for the shorter stages between seadromes is attractive. Whether this reduction in transport cost is sufficient to offset the great cost of the seadromes is doubtful. It appears that the tolls that it will be necessary to impose to make the project pay will be too high for the traffic to bear.

APPENDIX IX

Take-Off Conditions

The calculation of the take-off conditions of aircraft requires a detailed knowledge of the particular aircraft, including the aerodynamic characteristics of the aircraft and propeller, hydrodynamic characteristics of the hull, engine performance, condition of aerodrome, and many other factors; and even when these are reasonably well known, certain assumptions still have to be made and these, with the variation in the technique of take-off of different pilots, render close prediction difficult.

For this reason and also because a general outline only is here necessary, the following very rough figures are given to illustrate the take-off limitations.

Although not included in the following, "ground effect" is an important factor in connection with take-off. Ground effect through reducing the induced drag of the wing and the angle of attack for a given lift coefficient facilitates take-off. At the same time, a heavily loaded aircraft, having taken off, may find it impossible to climb beyond the zone of influence of ground effect which is confined to a height above the ground about equal to the span of the wings.

Symbols

W—gross weight of aircraft, lb.
P—rated horse power of engines.
D—air resistance of aircraft (without hull or floats in case of seaplane) without slipstream, lb.
R—reaction drag—ground or water resistance, lb.
F—effective accelerating force, lb.
T—propeller thrust corrected for slipstream resistance, lb.
V—velocity, ft. per sec.
S—wing area, sq. ft.
s—distance, ft.
t—time, seconds.
g—acceleration of gravity, ft. per sec. per sec
$q=\frac{1}{2}\rho V^2$—dynamic pressure, lb. per sq. ft.
ρ—mass density of air, slugs per cu. ft.
μ—coefficient of rolling friction.

Subscripts

0—at beginning of ground run.
1—at take-off.
m—mean during take-off.
w—wind.

The take-off is usually analyzed in three stages, the ground run up to unstick speed, the change of flight path, through an arc to climbing attitude, and climb to clear an obstacle of given height. It will be sufficient to consider only the first stage here.

The minimum speed of flight is simply given by

$$V = \sqrt{\frac{1}{C_{L\max} \cdot \frac{\rho}{2}}}\sqrt{\frac{W}{S}}$$

The aircraft may be stalled off at minimum speed. In the case of a seaplane it may be necessary to stall off the top of a wave. Ordinarily the take-off speed may be possibly 10 per cent higher than stalling speed (which implies that the wing is operating at a C_L about 20 per cent less than $C_{L\max}$), in order that some reserve of lift may be available after take-off. Minimum take-off run or time, however, usually requires that the aircraft be stalled off. As already mentioned, ground effect permits the aircraft to take off at a speed below the minimum for flight at an altitude.

An expression for the length of the ground run has been obtained by integration from the energy equation by Dr. Martin Shrenk, as follows:

$$Fds = \frac{W}{g}\, d\left(\frac{V^2}{2}\right) \quad \text{and} \quad \frac{V^2}{2} = \frac{q}{\rho}$$

$$ds = \frac{W}{\rho g} \cdot \frac{dq}{F}$$

It is assumed that the propeller thrust decreases linearly with q and that the angle of attack is constant during the ground run so that the reaction drag and air resistance are proportional to q. Then

$$F = F_0 - \frac{F_0 - F_1}{q_1} \cdot q$$

and

$$ds = \frac{W}{\rho g} \frac{dq}{\left(F_0 - \frac{F_0 - F_1}{q_1} q\right)}$$

integrating, and determining constant of integration by the fact that $s = 0$ when $q = 0$

$$s_1 = \frac{W}{\rho g} \cdot \frac{q_1}{F_0 - F_1} \cdot \log \frac{F_0}{F_1}$$

A simplification can be effected by assuming, instead of a linear reduction in effective accelerating force from F_0 to F_1, that the mean accelerating force acts uniformly during take-off, then

$$F_m = \frac{F_0 + F_1}{2}$$

and

$$ds = \frac{W}{\rho g} \cdot \frac{dq}{F_m}$$

integrating

$$s_1 = \frac{W}{F_m} \cdot \frac{q_1}{\rho g} = \frac{W}{F_m} \cdot \frac{V_1^2}{2g} = \frac{W}{F_m} \cdot \frac{W}{S} \cdot \frac{1}{C_{L\max} \rho g}$$

The last formulae are in error less than 4 per cent where F_0 is equal to or less than twice F_1.

Shrenk indicates that the minimum ground run results when the run is made at an angle of attack approximately equal to that for minimum drag in flight, until the minimum flight speed is reached, when the aeroplane is pulled up to an angle corresponding to minimum flight speed and the aeroplane lifts off.

Assuming constant acceleration during take-off,

since $$s = \frac{V_1 t}{2}$$

$$t = \frac{W}{F_m} \cdot \frac{V_1}{g} = \frac{W}{F_m} \sqrt{\frac{W}{S}} \; \frac{\sqrt{C_{L\max} \rho}}{g\sqrt{2}}$$

Effect of Head Wind on Take-off.

The principal effect of a head wind is to reduce the ground speed for take-off to $V_1 - V_w$ together with a minor effect due to the resulting increase in propeller efficiency.

The take-off run is reduced to

$$s = \frac{W}{F_m} \frac{(V_1 - V_w)^2}{2g}$$

It is evident from this formula that the reduction in ground run due to a relatively light wind is appreciable. A wind of velocity equal to 10 per cent of the take-off speed reduces the ground run about 20 per cent.

The effective accelerating force is:

$$F = T - R - D$$

Air Resistance.

The air drag D is practically the same for modern aircraft whether seaplane or landplane.

Assuming constant attitude during take-off (angle of maximum lift) which is as accurate as other assumptions that have to be made, the air resistance increases from zero to a maximum in proportion to V^2. The resistance at take-off will be

$$D = \frac{W}{L/D}$$

where the value of L/D is that corresponding to maximum lift, which, in modern aircraft, will range from 7 to 9 depending on the cleanliness of design.

As the variation of drag with speed for constant angle is parabolic, the average air resistance during take-off will be $\frac{D}{3}$.

Taking $L/D = 8$ the average air drag is

$$D_m = \frac{W}{24} = 0.04\,W$$

Reaction Drag.

It is the difference between the water resistance of seaplanes and the ground resistance of landplanes that is responsible for the difference in the take-off performance of these two types of aircraft.

(*a*) Landplanes

The friction drag $\quad R = \mu W_m$

W_m is the load on the ground, which equals the difference between the gross weight and the air lift and decreases from W to zero. As the variation of lift follows the same parabolic law as that of the drag during take-off, the average ground reaction during take-off is $\frac{2}{3} W$ and the mean reaction drag is

$$R_m = \frac{2}{3} \mu W$$

μ depends upon the nature of the take-off surface. For reasonably good conditions, say hard turf and short grass, a conservative value is $\mu = .06$.

Then $$R_m = 0.04\,W$$

(*b*) Seaplanes

The familiar form of the curve of water resistance of a hull during take-off plotted on speed has been shown by Gouge to be approximated by a parabola, the maximum hump resistance ranging from 0.16 W for a good hull to 0.25 W for a rather poor one.

On this basis the average water resistance during take-off will be 2/3 of the maximum or say

$$R_m = 0.10\,W$$

The water resistance of the hull includes the air drag.

Effective Propeller Thrust.

The thrust can be made sensibly the same for seaplane and landplane.

A reasonable assumption is that

$$T = K \cdot P$$

where the constant K depends on the pitch angle and speed of the propeller and varies from 3.4 for direct drive and fixed or two pitch

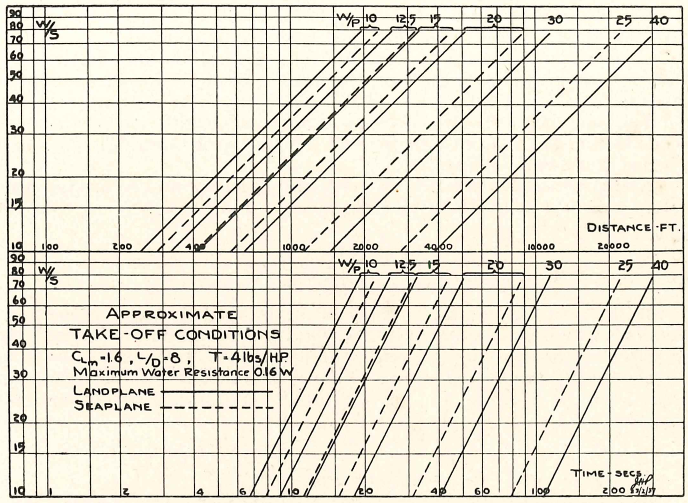


Fig. 25—Approximate Take-Off Conditions.

propellers to 4.2 for geared engines with constant speed propellers. An average value may be taken as 4.

Assume the propeller thrust constant during take-off and equal to 4 P.

Average Effective Accelerating Thrust.

(*a*) Landplanes

Using average values

$$\begin{aligned} F_m &= T - R - D \\ &= 4P - 0.04\,W - 0.04\,W \\ &= 4P - 0.08\,W \\ &= \left(\frac{4}{W/P} - 0.08\right) W \end{aligned}$$

and $$\frac{W}{F_m} = \frac{12\frac{W}{P}}{50 - \frac{W}{P}} \text{ roughly}$$

(*b*) Seaplanes

$$\begin{aligned} F_m &= 4P - 0.10\,W - 0.04\,W \\ &= 4P - 0.14\,W \\ &= \left(\frac{4}{W/P} - 0.14\right) W \end{aligned}$$

and $$\frac{W}{F_m} = \frac{7\frac{W}{P}}{30 - \frac{W}{P}}$$

It has been found that in many cases the acceleration during 2/3 or more of the take-off run is sensibly constant and hence the net accelerating force must be approximately constant.

Finally

For landplanes

$$s = \frac{12\frac{W}{P}}{50 - \frac{W}{P}} \cdot \frac{V_1^2}{2g} = \frac{12\frac{W}{P}}{50 - \frac{W}{P}} \cdot \frac{W}{S} \cdot \frac{1}{C_{L\max} \rho g}$$

For seaplanes

$$s = \frac{7\frac{W}{P}}{30 - \frac{W}{P}} \cdot \frac{V_1^2}{2g} = \frac{7\frac{W}{P}}{30 - \frac{W}{P}} \cdot \frac{W}{S} \cdot \frac{1}{C_{L\max} \rho g}$$

For landplanes

$$t = \frac{12\frac{W}{P}}{50 - \frac{W}{P}} \cdot \frac{V_1}{g} = \frac{12\frac{W}{P}}{50 - \frac{W}{P}} \sqrt{\frac{W}{S}} \cdot \frac{\sqrt{C_{L\max} \rho}}{g\sqrt{2}}$$

For seaplanes

$$t = \frac{7\frac{W}{P}}{30 - \frac{W}{P}} \cdot \frac{V_1}{g} = \frac{7\frac{W}{P}}{30 - \frac{W}{P}} \sqrt{\frac{W}{S}} \cdot \frac{\sqrt{C_{L\max}\,\rho}}{g\sqrt{2}}$$

The formulae are plotted in the accompanying Fig. 25.

For landplanes, the take-off distance is important, to reduce the size of aerodromes and runways required, while for seaplanes the take-off time is important to reduce the punishment of the hull by waves and to permit take-off from small or crowded harbours.

It is evident from the foregoing formulae that the take-off distance increases as the gross weight, as the square of the take-off speed and hence as the wing loading and with increase of power loading.

The take-off time increases as the gross weight, as the take-off speed and hence as the square root of the wing loading, and with increase of power loading.

Evidently also cleanness of both aerodynamic and hydrodynamic design improve take-off as does condition of the runway or take-off surface.

APPENDIX X

Fixed Long Run Shore Catapult

With the limited space available on shipboard, the accelerations are necessarily high in ship catapults. On the other hand, with relatively unlimited space available on land, the length of the track can be long and the accelerations moderate. This is illustrated by the figures in the following table, for two ship catapults and for a suggested land catapult.

Catapult	Acceleration run	Weight of aircraft	Launching m.p.h.	Speed f.p.s.	Aver. f.p.s.[2]	Accel. g	Time sec.	Accel. force
Bremen	65 ft. 0 in.	4 tons	62.2	91	63.7	1.98	1.43	$2W$
Ostmark (Heinkel K9)	103 ft. 9 in.	15 tons	93.0	136	89.2	2.77	1.53	$2.8\,W$
Land	2,000 ft. 0 in.	25 tons	100.0	147	5.4	0.167	27.4	$W/6$

Evidently, the accelerations need not be prohibitive in land catapulting. An acceleration of 0.16 g is rather greater than that in an electric train, but less than that possible in a motor car.

The general arrangement of the proposed land catapult is as follows:

Track

There are two possible arrangements of the track worth considering: one employing a long fixed track and the other using a shorter track capable of rotation. If the winds at the site of the station are reasonably constant in direction, the former is preferable because of its lower cost and longer possible run. If the winds vary widely in direction, the latter is better, since it permits full advantage to be taken of the assistance of the wind in launching and the car is largely relieved of lateral forces.

The fixed straight track is laid in the direction of the prevailing wind and may have a slope downward in the direction of launching. The track is of standard railroad construction and can be built over quite rough terrain using, where necessary, standard railroad practice in the matter of fills, trestles, etc. Use of the track permits take-off from a site where the cost of construction of an aerodrome would be prohibitive. In the case of marine aircraft, the track and car permits the use of smaller protected waters since an aircraft can alight in a much smaller harbour than that from which it can take-off. In this case, if the prevailing wind direction is suitable, the track can be built along the sandy beach or rocky shore of the harbour or bay or of a stream running into it.

For the rotating track, latticed girder construction is used and rotation provided for by supporting the girder at about the quarter points, on two cars running on a large diameter circular track (complete or arc only) or alternatively, by pivoting at one point and using one car on a track of twice the diameter. Beyond the supporting cars, the girder is a cantilever and, at the launching end, can be relatively light because the weight of the aircraft is here becoming air-borne.

The figure given for the average acceleration, using a track 2,000 ft. long, indicates that a much shorter track can be used without encountering excessive accelerations. A rotating track would necessarily be shorter, possibly not over 1,000 ft. long. In either case, length must be provided for deceleration of the car following the launch.

Car

The size, shape and arrangement of the car will depend upon the type of drive, type of aircraft, the track and other conditions.

The external form of the car should be carefully designed, possibly after wind tunnel tests, in order that the resistance and interference with the air flow about the aircraft may be reduced to a minimum. If the car produces much disturbance of the flow of air, a difficult change of flight conditions may be encountered during the launch when the aircraft passes beyond the influence of the disturbance.

For the propulsion of the car, there are several alternatives, depending on the length of the track and local conditions. A cable drive appears promising, particularly for a short track although mine practice proves long high speed cable drives practicable. A cable drive for the car of the model testing basin at Ottawa has proved satisfactory. With cable drive, the car can be light, but the weight of the cables will increase the required accelerating force.

For long tracks, self-propelled cars driven by gasoline, Diesel or even steam engines may be used. The tractive effort required will be equal to the sum of the drag of the aircraft, car resistance and accelerating force. The resistance of the car, including rolling and journal friction and air drag will increase with speed up to about 25 lb. per ton at top speed. This is relatively small and, together with the drag of the aircraft, may be assumed to be taken care of by the thrust of the airscrews of the aircraft.

Assuming constant acceleration, the accelerating force for the suggested catapult of the foregoing cable will be one-sixth the total weight of the aircraft and car. A reasonable value for the coefficient of traction between wheels and rails is 0.25 and, as this exceeds the accelerating force coefficient, it is clear that any weight of car will provide sufficient traction if the lift of the wings does not exceed one-third the weight of the aircraft. To reduce the force and power for acceleration, the weight of the car should be kept low. If it is assumed equal to one-half the weight W of the aircraft, the average total accelerating force will be $W/4$, traction will be $3/8\ W$ and the maximum power (constant acceleration) required will be about $0.07\ W$ hp. For a 25-ton aircraft, the accelerating force will be 12,500 lb. and the maximum power 3,500 hp.

However, the accelerations would not, in practice, be constant, but vary, being high at the beginning of the run and dropping to zero at the instant of launching and the maximum power required would then be much less than that given.

The principal handicap of wheel traction drive for the car is the weight of the motive power and the vicious circle that results from weight requiring power to accelerate and power, in turn, requiring weight.

An attractive form of drive is by means of aircraft engines and airscrews. The aircraft engine is the lightest type of prime mover, hence the car can be very light and traction difficulties are avoided. Airscrews designed for the particular low speed conditions are used and the engines are operated at full take-off power for the short time necessary for the launching.

For the example considered, assuming the car weight is reduced to $W/4$ with airscrew drive, the accelerating force (constant acceleration) will be about $W/5$ and the maximum power about $.04\ W$ or, for a 25-ton aircraft, 10,000 lb. and 2,000 hp., respectively. By using four 500-600 hp. engines, mounted on cantilever outriggers on each side of the car, the airscrews will be well below the aircraft wings and an effective drive provided.

An operator, riding on the car, controls the speed, to accelerate in the desired way and, after the launch, brings the car to rest.

Cradle

The aircraft cradle is pivoted in the car to permit the aircraft to align itself (weather-vane) with the relative wind. The aircraft is cradled at a fixed incidence, slightly below that of maximum lift and held in place by a locking device. On reaching launching speed, acceleration is reduced to zero and the speed of the car held constant until the pilot signals and releases the lock. The car then begins to decelerate and the aircraft flies off.

With ample accelerating thrust available from the car, there is no need to reduce the aircraft drag during acceleration, by cradling the aircraft on a tilting cradle at the incidence of minimum drag and, at the instant of take-off, increase the incidence by use of the aircraft controls. A slight freedom in tilt may be desirable to enable the pilot to feel if the aircraft controls are set appropriately for the speed at launching.

The aircraft may be lifted from the ground or water and placed on the cradle by means of a rotating crane as in the D.L.H. depot ships.

APPENDIX XI

Mayo Composite Aircraft

The reported construction and performance details of the composite aircraft, now under construction, are as follows:

Upper Component—'Mercury'

Four-engined, high wing, float seaplane—span 73 ft. 0 in.; length 51 ft. 0 in.; height 20 ft. 3 in.; wing area 611 sq. ft.; tare weight 9,760 lb.; gross weight 20,000 lb.

Engines—Four Napier Rapier, Series V, 16-cylinder, air-cooled H engines; dry weight 720 lb.

Power—rated 315 hp. at 10,000 ft.
maximum, 340 hp. at 13,000 ft.
maximum r.p.m. 4,000.

Propellers—Fixed pitch, wooden.

Performance—Specified range 3,500 miles with 1,000 lb. of mail. Predicted range 3,380 miles in still air or 2,150 miles against 60-mile headwind, with possibly 4,000 lb. mail.

Lower Component—'Maia'

Four-engined, high wing, flying boat, similar to Short Empire boats—span 114 ft. 0 in.; length 84 ft. 11 in.; height 32 ft. 7 in.; wing area 1,750 sq. ft.

Engines—Four Bristol Pegasus.

Composite Aircraft

Combined horsepower nearly 5,000.

Power loading about 11 lb. per hp.

Combined weight about 42,000 lb.

APPENDIX XII

The Ice Hazard

Until the advent of modern commercial air transport, operating on fixed routes, on regular schedules, in all seasons and in all kinds of weather, the ice hazard was not serious. In recent years, however, there have been an increasing number of interruptions to commercial services and forced landings, some disastrous, due to this cause.

The meteorological and physical conditions and processes leading to the formation of ice on aircraft are complex and are not yet properly understood. Hence the hazard is difficult to forecast accurately even with the best of meteorological organizations.

Character of the Ice Deposit

The nature of the ice formation varies with the conditions. Three principal types of deposit are generally recognized:

1. Clear ice or "glaze," normally smooth but which may be rough when mixed with snow or sleet or ridged when freezing is slow. The ice builds up on the leading edge in a blunt nosed shape, i.e., "mushrooms," tapering sharply to the rear. Occasionally the wings are covered both top and bottom, and icicles form at the trailing edge. The ice adheres tenaciously. This type of ice has the most serious effects.
2. Hard, white, opaque granular deposit or "rime" which builds forward from the leading edge in a sharp-nosed shape. Rime is encountered more frequently but generally adheres less tenaciously than clear ice, except at very low temperatures, and is less serious.
3. Frost, a light feathery crystalline deposit with little adhesion, which is not dangerous.

Conditions

Ice deposition in serious amounts occurs practically only when the aircraft is in some form of visible moisture, cloud, fog, rain or mist, at temperatures below and close to 32 deg. F. and high relative humidity, 90 per cent or over.

Supercooled water droplets in the air remain liquid at temperatures below freezing, and have been observed at surprisingly low temperatures, as for instance −4 deg. F. in America, −29.2 deg. F. in fog in Greenland and −37.2 deg. F. in Antarctica. The supercooled state is unstable, and on collision with the aircraft the droplets freeze. On impact, part of the droplet freezes, forming a slushy mixture at 32 deg. F. which changes to ice as the latent heat is removed through evaporation or conduction to the structure. The rapidity of freezing depends on the degree of supercooling. Droplets at, or a few degrees below 32 deg. F. freeze slowly to form clear ice; if highly supercooled, at several degrees below freezing, the droplets freeze rapidly to form rime. Apparently large droplets, as in rain, generally form clear ice and the minute droplets of clouds form rime. If droplets of different sizes are present, the deposit may be either clear ice or rime and if the former, the coating will be rough. Most rapid icing usually occurs where there is temperature inversion and rain is falling from comparatively warm clouds above on a layer of air or cloud at a temperature below freezing in which the aircraft is flying.

A thin coating of ice may be formed in clear air above cloud, from the moisture collected in passing through the cloud.

Occasionally icing occurs at temperatures above freezing when the aircraft is flying in a layer of dry air on which rain is falling from above. Evaporation of the liquid film on the aircraft causes, as long as the surface is wet, a temperature drop of several degrees depending on the relative humidity, sufficient to result in freezing especially since the rain drops falling through the dry layer are themselves cooled by evaporation, below air temperature, and may be supercooled. Cooling also results from adiabatic expansion of the air flowing over the wing surface. The latter cooling is greatest at the points of highest velocity.

The formation of frost on aircraft is a result of sublimation and therefore dependent on a state of supersaturation with respect to ice. Frosting may occur when, after being cooled to a low temperature in a cold strata, an aircraft descends rapidly into a highly saturated layer at a higher but still subfreezing temperature. Frosting may also occur in flight in nearly saturated air at a temperature below freezing due to adiabatic cooling.

Sleet alone does not collect on aircraft, but mixed with rain may form a rough and dangerous coating. Similarly, dry snow does not adhere, but a mixture of snow and rain or cloud droplets will likely result in a heavy deposit of frozen slush. Clouds composed of ice spicules do not form any appreciable deposit.

The structural material of the aircraft is of importance only insofar as it affects the start of the ice formation. The rate of growth, after the initial coating, varies but little. There is some indication that highly polished surfaces reduce the adhesion of ice, and that roughness such as seams and rivets favour icing. Thick wing monoplanes appear to be less susceptible to icing than thin wing biplanes.

High speeds favour icing through increasing the quantity of moisture encountered in a given time, the rate of heat dissipation, and the adiabatic cooling.

Records of autographic meteorological instruments carried by aircraft indicate that in the United States clear ice may begin to form at temperatures from 33.8 to 1.4 deg. F. and rime from 33.8 deg. F. to −4 deg. F. but that most frequently clear ice commences at 32 deg. F. and rime at 28.4 deg. F. Rime occurs two or three times as frequently as ice. Both types are encountered most frequently at elevations between 1,500 and 5,000 ft. and somewhat less often at 8,000 to 10,000 ft. for clear ice and 13,000 to 15,000 for rime, but icing may be met with at any elevation within the range covered, i.e., up to 18,000 ft. The region from 6,500 to 8,000 ft. is one of low frequency for both types.

Clear ice and rime form most frequently in strato-cumulus clouds, with high frequencies also, for clear ice in alto-stratus and for rime in stratus clouds. No deposits were reported in cumulus clouds doubtless because flights were made before daylight. Cumulus and strato-cumulus are known to be favourable to icing.

Effects

The effects of the accumulation of ice on aircraft are numerous and serious.

The most serious effect of icing is the deformation of the aerodynamic forms, particularly of the wing and tail surfaces and the resulting adverse effects on performance. Lift is decreased, and drag increased, to such an extent in many cases that flight cannot be maintained even at full throttle. The cleaner the aerodynamic design, the more quickly are the effects apparent.

The malformation resulting from ice causes vibration of wires, wing tips and tail which, at high speed, may start very suddenly and may cause failure of the part.

The increase in weight due to icing is generally of secondary importance. The additional load is partly offset by the weight of the fuel consumed during the accumulation of the ice. The effect of the weight of the ice is chiefly noticeable in banking.

In spite of centrifugal force, the airscrew is also subject to icing. In addition to the effects on efficiency, deposits on the airscrew constitute a serious hazard if thrown off irregularly. Balance is destroyed and vibrations, in extreme cases of a disastrous character, are caused. To minimize vibration, throttling is often necessary, leading to more rapid icing of the airscrew. The disturbances are amplified by the gears in a geared engine.

Ice may interfere with the movement of control surfaces and of external controls. The latter is not serious in modern aircraft with interior controls.

The power plant may be affected through the freezing of radiator shutters, clogging of air intake screen and closing of tank and crank case vents if they project into the air stream.

Instruments are also affected through the icing of such elements as Venturis, air speed heads, windmills and radio antenna, both trailing and fixed.

Windows may be coated, and, if sliding, may freeze tight and prevent their operation in landing

Printed in Canada